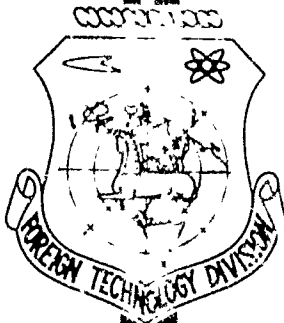# TRANSLATION

NAVAL AIR DEFENSE OF SHIPS

By

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FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

WRIGHT-PATTERSON AIR FORCE BASE

OHIO

EDITED TRANSLATION

NAVAL AIR DEFENSE OF SHIPS

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INTRODUCTION

It is the function of air defense to frustrate all enemy aerial

attacks. The origin and development of air defense is associated with

the growth and development of air forces and other means of aerial

combat. As early as the first World War the combat operations of the

naval air forces led to the establishment of special naval anti-

aircraft forces and facilities, and it also became necessary to imple-

ment measures to combat enemy air forces. Pursuit aircraft and anti-

aircraft artillery made up the most important means of counteracting

the enemy air force.

Initially, air-force operations against ships at sea and in port

were one-time affairs and exerted little influence on the outcome of

naval battles. Air defense was given the task of thwarting enemy air

strikes. It was only with the extensive resort to air forces in the

second World War and during the "Great Fatherland War" that a radical

change took place in the nature of naval combat operations. Ships had

to maintain continuous guard against surprise aerial attacks.

While during the first World War approximately 2.5 percent of the

total number of ships sent to the bottom could be attributed to air

forces, the corresponding figure for the second World War increased to

42 percent. Moreover, this percentage includes only such major naval

units as battleships, aircraft carriers, cruisers, and destroyers. At

the present time the air forces take on ever-increasing significance.

The use of rockets, nuclear weapons, and jet aircraft, capable of op-

erations at great altitudes, imposed greater requirements on naval air

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combat operations at sea.

In the period between the first and the second World Wars the power developed by engines increased by a factor of 3.5, and flight speeds increased by a factor of almost 2.5. During this period bombers increased their range by a factor of 5, bomb loads and ceilings doubled, and the total number of aircraft more than doubled.

Prior to and during the second World War naval air forces grew into a major branch of naval forces. The naval air forces today represent a significant striking force and exhibit great maneuverability; by no means can they be considered only capable of operating in conjunction with other branches of the navy, but rather are capable of executing independent effective strikes against surface vessels, transport, submarines, and coastal targets.

An increasing number of aircraft types assumed permanent positions in naval weaponry; these types included bombers, pursuit aircraft, fighter-bombers, reconnaissance aircraft, torpedo planes, and special aircraft.

Torpedo planes have the function of destroying enemy ships and transport vessels with bombs or torpedoes. The special aircraft, among others, have the function of carrying out submarine patrols. It is their function, independently or in conjunction with other forces, to seek out enemy submarines, to engage these, and to destroy these submarines with anti-submarine weapons.

Air-force tactics against naval targets were developed prior to the second World War, and these were subsequently employed during the period of the war. The resulting tactic of bomb and torpedo strikes, as well as placement of mines, is still of significance today.

Airplanes are capable of carrying out aerial strikes in horizontal flight or by diving (Fig. 1). In horizontal flight bombs are released

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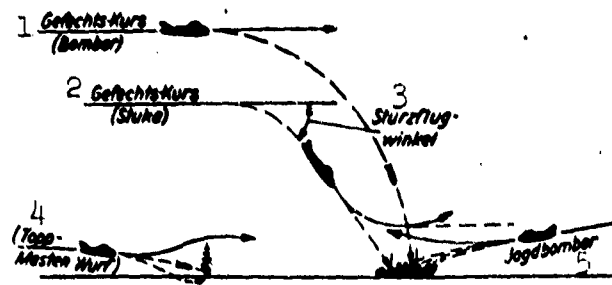
Fig. 1. Various aerial tactics
against ships. 1) Flight heading
(bomber); 2) flight heading (Stuka);
3) dive angle; 4) deck-mast release;
5) fighter-bomber.

against single moving ships as well as against groups of vessels. As a
result, airplanes can operate from various altitudes and directions,
either individually or in groups, at times of their own choosing and
under any weather conditions. The targets may be detected by visual-
optical means, or electronically. Air strikes under difficult condi-
tions thus became possible because of the development of special radio
bombsights. On the negative side of bombing from horizontal flight we
have the relatively long time required for sighting and the low accu-
racy, particularly in the case of bombing from high altitudes. Depend-
ing on the flight altitude, if possible an aircraft attacks a ship
cross beam or from behind.

Dive bombing, considerably more accurate than the release of
bombs from horizontal flight, is employed primarily against small tar-
gets. As a rule, aircraft in this case attack from medium and low al-
titudes at a dive angle of 40° to 80°. The pulling out of the dive de-
pends on the altitude from which the dive is started. This method of
releasing bombs gained widespread acceptance during the course of the
second World War.

A special form of horizontal bomb release is the low-level flight
release to damage the sides of a ship, or below the water line, by con-

cussion or direct hit. This type of release ·.ay also be known as the
deck-mast release. This latter designation refers to the flight tactics
involved, since the aircraft is flying toward the target at mast level
and releases its bombs at maximum speed in horizontal flight (Fig. 1).
This approach is simple in application, ensures high accuracy, and may
be practiced by a great variety of aircraft. It is for this reason
that this method was frequently employed during the course of the sec-
ond World War.

Fighter-bombers were usually sent in ahead of the main forces
(bombers and torpedo planes) in order to reduce the firepower of the
[enemy] ships with their on-board weapons and bombs (Fig. 1). Moreover.
fighter-bomber aircraft were frequently employed independently for pur-
poses of destroying small ships and landing craft. These aircraft at-
tacked these targets at high speed and from low altitudes (not above
700 meters). As a rule, these attacks surprised the ships.
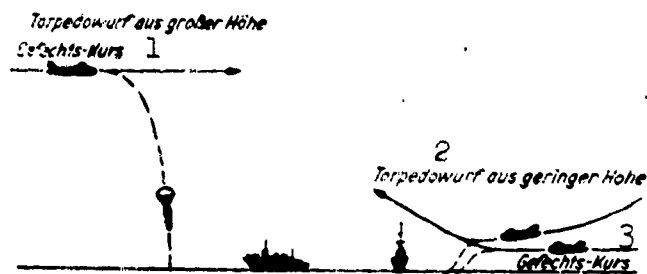
Fig. 2. Torpedo release. 1) Torpedo
release from great height; 2) tor-
pedo release from low height; 3) at-
tack flight heading.

Torpedo planes (Fig. 2) are used primarily against larger ships
and transport vessels. Depending on the situation and the design of
the torpedo, the torpedoes may be released from both low and high alti-
tudes. In the case of low-level flight a torpedo is released somewhere
between 50 and 300 meters. In the case of higher altitudes, the torpedo
is not released below 2000 meters. Torpedoes are equipped with special

stabilizer fins to reduce speed upon entry into the water. There is some advantage to be gained by having torpedo planes attack simultaneously from high and low altitudes. In this case, the high-altitude torpedo planes draw the fire of the enemy ships so as to set up the successful attack of the low-flying torpedo planes which are approaching the target in low-level flight. Moreover, torpedo planes can be employed to lay mines in order to blockade enemy ships in their bases and to disrupt naval communications.

Submarine patrol planes are part of the submarine-defense forces. They are more maneuverable and can find and destroy enemy submarines quickly, in a relatively large area of open sea. Surfaced submarines are spotted electronically or visually and then destroyed with anti-submarine weapons (bombs, torpedoes, rockets).

Hydroacoustic buoys and instruments are used to disclose the pres ence of enemy submarines at great depths beneath the surface of the sea. The hydroacoustic buoys [sonobuoys] are equipped with sound pick-ups and a transmitter. These devices are dropped from aircraft at such points at which the presence of submarines is suspected.

Submarine-produced sounds are picked up by the buoy receivers and corresponding signals are sent by means of the transmitter to the aircraft. Upon receipt of such signals the aircraft drops additional buoy: in order to determine the exact position of the submarine.

The most effect ·. tactical deployment of aircraft against ships, in the opinion of specialists from the capitalist world, is a massive strike from various directions by aircraft of various types. Massive strikes may be carried out in groups of two, three, and more aircraft. The aircraft approach the target along a straight heading and then execute evasive maneuvers. The attack begins at the instant that the attack flight-heading is assumed and is ended with the release of the

bombs, torpedoes, etc. At this point the aircraft withdraw. As a rule, this withdrawal takes place at maximum speed. The attack flight-heading is necessary to provide the appropriate initial data for the bomb or torpedo attack. Because of technical advances in aircraft equipment it is today no longer absolutely necessary for velocity and heading to be maintained rigorously along the attack heading.

The development of reaction-thrust powerplants led to a significant rise in velocity, altitude, range, and aircraft payload.

During the course of the second World War fighter aircraft were capable of speeds of 650 km/hr; today speeds of 2000 km/hr can be attained. The ceiling has been raised from 12,000 to 20,000 meters and range has been increased from 1000 km to 4000 km.

The range of a medium bomber has been increased from 2500 km to in excess of 8000 km and flight speeds have increased from 500 to 1500 km/hr. The bombload has been raised from 4000 kg to more than 8000 kg, and the ceiling has been raised to a peak of 18,000 meters.

The greater speed, greater altitude, and improved range, as well as the new mass-destruction capabilities of aircraft, require the continuous improvement in methods involving the utilization of air forces.

The utilization of guided missiles at great altitudes and over greater distances is constantly on the rise. Because of the changeover to guided missiles, the number of bombers participating in an attack can be reduced and the use of nuclear weapons increases the effect.

The nuclear tests conducted at the Bikini Atoll by the USA demonstrated that ships of all classes suffer serious damage or are sunk at a distance of 800 to 1000 meters from the epicenter of an explosion in the air. The nuclear weapon exploded at that time had a TNT equivalent of 20 kilotons.

Let us present a number of brief comments regarding the use of
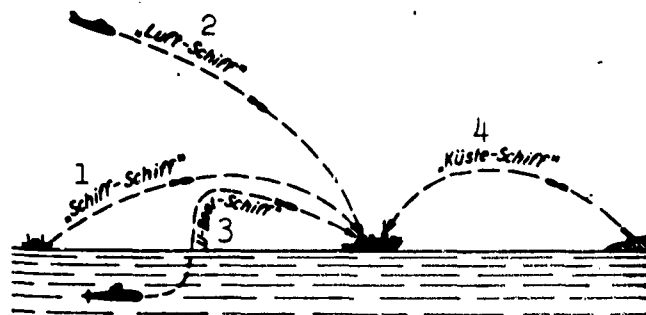
Fig. 3. Possible rocket applications against naval targets. 1) "Surface-to-surface"; 2) "air-to-surface"; 3) "submarine-to-surface"; 4) "coast-line-to-surface."

rockets against naval targets. At the present time rockets have attained such a high degree of development that under present conditions they represent an extremely dangerous force against ships. From the tactical standpoint rockets against naval targets are divided into the following classes: "surface-to-surface," "air-to-surface," "coastline-to-surface," and "submarine-to-surface" (Fig. 3).

All of these rockets are intended for the destruction of naval targets and are launched from surface vessels, aircraft, submarines, or ground positions. Military specialists from the capitalist countries are of the opinion that the combat utilization of rockets at the present time has not yet been worked out with sufficient thoroughness. Nevertheless, it may safely be stated that rocket-equipped surface vessels will be able to carry out the same missions as the heavy artillery and aircraft carriers. The military forces of the USA have not only equipped aircraft with rockets, but have also provided helicopters with special rockets for anti-submarine warfare.

The range of modern rockets is very great. It may amount to several hundred kilometers, and even several thousand kilometers. Thus the range of artillery and torpedoes is greatly exceeded. Moreover, rockets exhibit a relatively high accuracy. As demonstrated statistic-

ally, the probability of a hit against heavy surface vessels during the first World War for heavy-caliber artillery amounted to some 3 percent, approximately 11 percent for torpedoes, and 1 percent for aerial bombs. In the second World War the probability of an artillery hit came to 4 percent, 15 percent for torpedoes, and 7 percent for aerial bombs. The probability of a rocket hit is significantly higher than the above-mentioned weapons. According to foreign experimental data, the hit probability for rockets is at least 46 percent. This high accuracy is achieved through the control and guidance equipment installed in rockets. The aerial combat operations against ships considered to this point show that it is the primary function of naval air defense to destroy approaching rockets and enemy aircraft that have penetrated the air defense system, and to prevent these from assuming their operational flight headings and releasing of their destructive force.

Despite the shortcomings characteristic of conventional artillery, all classes of ships presently still employ this form of weapon, particularly in the case of small vehicles on which it is impossible to mount anti-aircraft rockets, because these are heavy and take up considerable space. Aboard small ships automatic weapons remain the primary means of self-defense against aerial attacks.

MODERN ANTI-AIRCRAFT FACILITIES ABOARD WARSHIPS

Anti-Aircraft Artillery

Modern warships are fitted out with a so-called weapons-system for operations against aerial targets. The weapons system includes the actual weapons, the corresponding ammunition, and the fire-control equipment. A weapons system of this type can provide for the direction of fire against air, naval, and coastal targets. The primary function of this system is the timely detection of enemy aircraft and unmanned air weapons, the determination of their heading and approach elements,

and finally to repulse the attack through fire of the weapons.

Anti-aircraft artillery is subdivided into

● light anti-aircraft artillery

● medium anti-aircraft artillery and

● anti-aircraft rockets.

The light anti-aircraft artillery generally includes the caliber range from 20 to 76 mm. The medium anti-aircraft artillery encompasses calibers from 85 to 100 mm. The anti-aircraft rockets are not classified according to caliber.

Depending on range, the light anti-aircraft artillery is used for operations against aerial targets at low and medium altitudes (below 6 km); the medium anti-aircraft artillery, on the other hand, can be employed to direct fire against aerial targets at medium and great altitudes (up to 15 km). Anti-aircraft missiles may be employed against aerial targets at medium and high altitudes as well as against targets flying above 15 km. Light anti-aircraft artillery can be found aboard all warships, whereas the medium anti-aircraft artillery is primarily encountered aboard large warships. Anti-aircraft rockets are to be found primarily aboard vessels at least the size f frigates.

Weapons with a caliber of less than 20 mm are as a rule regarded as machine guns. These are best employed aboard small boats.

Modern artillery weapons are generally linked with fire-direction equipment capable of ensuring effective fire. The following instrument groups are included among the fire-control equipment:

Target Detection and Aiming Equipment

This equipment is used for target detection and the approximate determination of target coordinates (range, bearing, elevation). This equipment grouping includes radar stations and optical instruments (rangefinders, target indicators).

Equipment for Observation and Determination of Current Coordinates

At any given instant of time, coordinates provide the position of a target with reference to a given combat station. This group of instruments is housed in the so-called stabilized fire-control points (FLS [Feuerleitstand]). With this equipment targets are continuously kept under observation, target coordinates are continuously determined, and all information is supplied to the computers. The latter are housed in the computer center of the ship and are assigned the task of providing fire-control settings.

Fire-Control Computers

The function of this equipment group is to determine weapon settings and to calculate fuse settings. The basic units of this group are the computer (Reg [Rechengerät]) and the coordinate converter (KU [Koordinatenumwandler]) which receives the bearings from the computer without consideration of the roll and pitch angles and whose function it is to determine the total angles for purposes of vertical and horizontal aiming (also known as elevation and directional settings). In other words, the coordinate converter destabilizes the computer-determined values for nonstabilized weapons, thus taking into account the phenomena brought about by the motion of the sea.

Fire-Control Equipment

This equipment is connected directly to the weapons. It includes the sensing elements for total vertical and horizontal sighting angles and in the case of stabilized weapons the pickup for the settings of the trunnion axis. In addition, this group includes the pickup for the fuse-setting time.

Signaling Instruments and Firing-Complex Equipment

This equipment is employed to monitor the weapons, to determine whether they are ready to fire, and capable of firing salvos.

ANTI-AIRCRAFT WEAPONS

General-purpose weapons exhibit a number of features relative to shipboard weapons which can be employed only against naval and coastal targets.

The use of heavy weapons against aerial targets requires significant firing arcs and barrel elevation. The vertical and horizontal aiming speeds with such general-purpose weapons must be high (10 to 30 degrees per second), and this also applies to the fact that the rate-of-fire must be fast. Medium-caliber weapons attain a rate-of-fire of 15 to 20 rounds per minute. Light-caliber weapons are today in a position to get off several hundred rounds per minute.

The design of the anti-aircraft weapons must satisfy these conditions and be capable of meeting the imposed requirements; for this reason, the specific features of installation and utilization under shipboard conditions must be taken into consideration.

On the basis of general design features, anti-aircraft weapons intended for use aboard ships are divided into turret, deck-turret and deck weapons.

These weapons may be mounted aboard ships in stabilized or nonstabilized form.

In the case of turret weapons (Fig. 4) all instruments, attendant personnel, and ammunition conveyor systems are protected against shells and shrapnel by means of armor. The armoring is generally up to 15 mm thick. The rotating portion of the turret mount consists of the platform carrying the weapon, the aiming mechanisms, the loading equipment, a portion of the fire-control equipment, and the gun crew; in addition, there is a lower platform on which are mounted all auxiliary units, the "ready" ammunition, and the pickup point at which the conveyor system from the magazine terminates.

Fig. 4. Triple turret weapons (the
two forward gun mounts) and the
double deck turret weapons (at the
back and to the starboard) aboard
the cruiser Canberra of the US Navy.

Fig. 5. Triple turret weapons (forward and astern, 2 each)
and deck turret weapons (3 double gun mounts on the port
side visible) aboard the Soviet cruiser Shdanow [Zhdanov].

In the way of explanation it should be stated that "ready" ammuni-
tion refers to a small quantity of ammunition that is intended for the
immediate opening of fire in the event that an unanticipated target
appears and it is impossible to await the supply of additional ammuni-
tion from the magazine.

One feature of turret-mounted weapons is the fact that the plat-
form, the ammunition conveyor system, and the magazine combine to form
a single system. In the majority of cases turret-mounted weapons are
housed in twin turrets, these being found primarily as part of the ar-
mament of surface vessels (aircraft carriers, cruisers, and destroyers).

In the case of deck turret weapons (Fig. 5) the platform and the

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ammunition conveyor systems are again protected by means of armor plat-
ing designed to withstand direct hits, but they are not as completely
enclosed as in the case of turret-mounted weapons. The magazine and
the turret do not form a closed system, and the magazine is separated
from the turret. The deck-turret weapon again consists of an upper and
lower platform. The upper platform is part of the rotating portion of
the weapon, while the lower platform, on the other hand, is fixed per-
manently to the deck. The lower platform carries the "ready" ammunition
the conveyor systems from the magazine terminate here, and it also car-
ries the supply line for the movement of the "ready" ammunition to the
upper platform, which is connected to the rotating platform. As a rule,
deck turret installations are stabilized. The rear portion of a deck-
turret weapon is open. During the course of firing, the shell casings
slide out of the turret through this unprotected portion. The lower
portion of the deck-turret weapon is also open. Thus good ventilation
for the turret is ensured and the bothersome effect of smoke is elim-
inated. As a rule, deck-turret weapons are used aboard aircraft car-
riers, cruisers, and destroyers. In most cases this form of weapon is
encountered in twin turrets.

The deck turret weapons need not always be connected to a lower
platform. In such cases, the ammunition is fed into the turret directly
from the deck. These weapons are included in the category of deck
weapons.

In the case of deck weapons (Fig. 6) the magazine and ammunition
conveyor system are completely separate from the weapon. The ammunition
conveyor system from the magazine terminates in the vicinity of the
weapon, above deck. The gun crew, a portion of the fire-control equip-
ment, and the aiming mechanisms are protected by armor set up in the
form of shields and screens around the weapons.
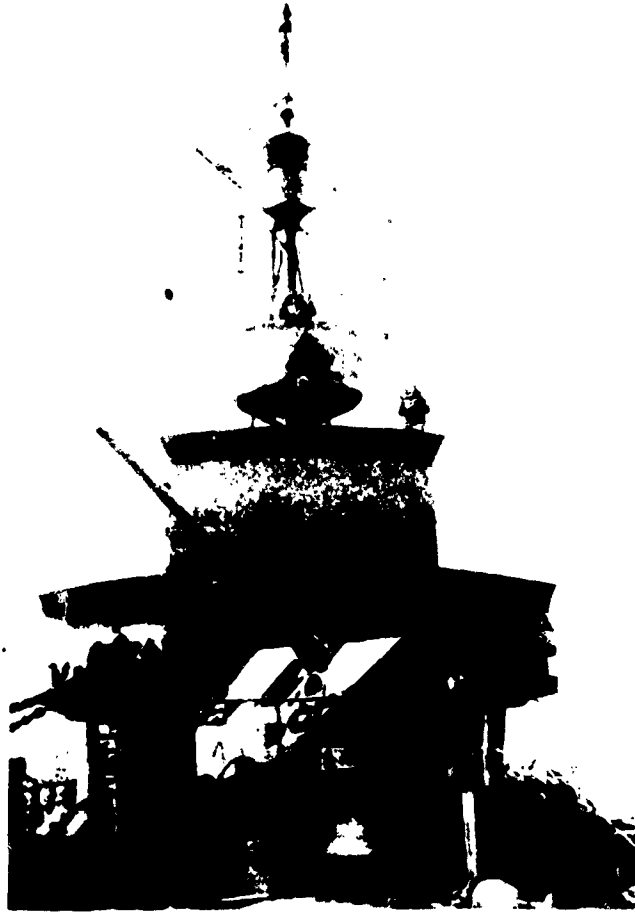
Fig. 6. Deck weapon aboard an MLR
ship of the People's Navy of the DDR
[German Democratic Republic].

As a rule, medium-caliber deck weapons are of the single and
double gun-mount variety. Light-caliber deck weapons are mounted in
groups of four. All surface vessels are equipped with deck weapons.
These weapons are simple in design, are easily serviced, and are not
very heavy. Deck weapons can also be stabilized.

All of the aforementioned weapon types can be divided into auto-
matic and semi-automatic weapons. In the case of automatic weapons,
the insertion of the shell, firing, and ejection of the casing proceed
automatically. In the case of semi-automatic weapons, only the breech
mechanism is opened automatically, the casing thus being ejected. All
medium-caliber weapons are included in this category of weapon.

The automatic action of the weapons is achieved through exploitation of the re oil energy that is attained as a result of the combustion of the ɾarge, and from the energy of the recoil system. Automatic weapons are generally equipped with wedge-type breechblocks and are operated with fixed ammunition. This ammunition is fed in with racks, in drums, or in belts.

Medium-caliber anti-aircraft weapons are equipped exclusively with wedge-type breechblocks and fire either fixed ammunition or separated cartridge ammunition. In the case of fixed ammunition the charge is contained in the shell casing and the shell is directly connected to the casing. In the case of separated cartridge ammunition the shell and the casing are separated. In this case, the shell is first inserted into the barrel, and then followed by the cartridge casing containing the charge.

In order to take advantage of the recoil energy after the discharging of the weapon, weapons of all calibers are provided with so-called counterrecoil equipment. This may appear in the form of hydraulic recoil brakes of either the hydraulic-pneumatic or recoil-spring variety, which serve the function of returning the recoiling parts to their initial positions.

To facilitate the aiming of the weapon during motion through water, deck-turret and some deck weapons have been stabilized. In the case of these stabilized weapons, the aiming procedure matches the aiming requirements of the ground-based weapons of ground forces. The stabilization of these weapons is achieved through the continuous maintenance of the trunnions of the weapons in horizontal position, while the ground plate of the weapon follows the motion of the ship. Stabilization facilitates aiming conditions and eliminates the effect of the rolling and pitching of the ship. Stabilized artillery weapons can be

aimed in three planes, i.e., in the horizontal and vertical planes, as well as in the trunnion plane. In the case of nonstabilized artillery installations, the aiming procedure can be carried out only in two planes, i.e., in the horizontal and the vertical planes.

Modern anti-aircraft weapons can be aimed in three distinct ways:

● automatically,

● semi-automatically and

● manually.

Automatic aiming is carried out by means of a remote-controlled servomotor. Thus extreme accuracy and such high aiming speeds are attained as are impossible with manual operation.

In the case of semi-automatic aiming, the gun layers first read the transmitted data from the corresponding receivers and then complete the sighting with the power drives provided for this purpose.

In manual operation, the ammunition is brought to the platform mount by means of special conveyor systems which are driven either electrically, hydraulically, or manually. It becomes evident that a modern anti-aircraft weapon has complicated technical equipment at its disposal and can be serviced only by specially trained personnel.

On the following pages a brief explanation of the technical construction of medium-caliber anti-aircraft weapons will be undertaken, and then a number of technical features of light-caliber anti-aircraft weapons will be detailed.

Medium-caliber anti-aircraft weapons consist primarily of a cradle, a gun mount, and a base plate. The cradle with its trunnions is seated in the bearings provided for this purpose in the gun mount. Since the trunnion axis of a loaded weapon passes through the center of gravity of the cradle, vertical aiming is possible without great difficulty.
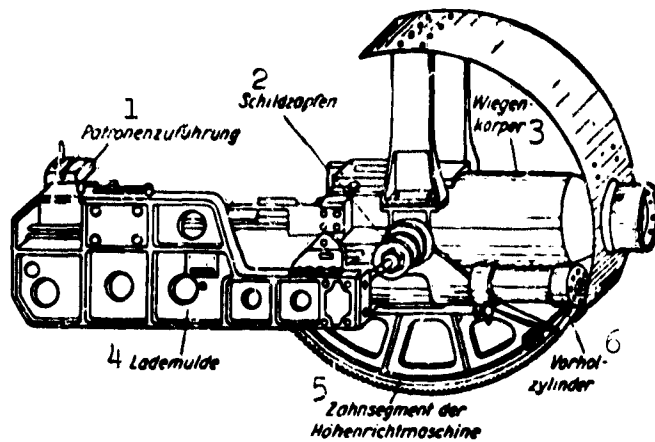
Fig. 7. The cradle of a weapon. 1)
Ammunition feed; 2) trunnion; 3)
cradle frame; 4) loading tray; 5)
toothed segment of elevation mechan-
ism; 6) recoil cylinder.

The cradle can carry one or two barrels. The breech plate which
carries the breech and semi-automatic mechanisms is generally screwed
onto the barrel jacket. Moreover, the piston rods of the counterreco:
devices are contained in the breech plate.

The counterrecoil devices are housed in the cradle. In addition,
the loading tray is attached to the cradle.

In the case of nonstabilized weapons, the gun mount and the bar-
rel carriage are part of the swivel mount. In the case of stabilized
weapons, the movable base of the weapon and the carriage are part of
the swivel section. The gun mount rests on the bearings of the pivot
ring. The roller bearing of the vertical pivot journal restricts the
horizontal movement of the pivot ring. On the one hand, the gun mount
provides the weapon with the ability to fire in all directions, and on
the other hand, it provides the connection between the cradle and the
elevation mechanism. The mounting supports of the gun mount ensure the
connection of the weapon to the pivot ring during firing while at sea
and moreover they protect the weapon against tipping over.

Power is supplied to the instruments through the appropriate

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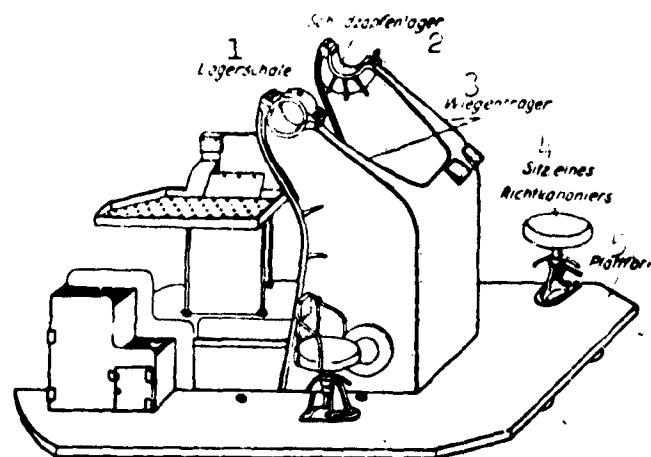
Fig. 8. Gun mount of a weapon. 1)
Bearing box; 2) trunnion bearing; 3)
cradle support; 4) gun-layer seat;
5) platform.
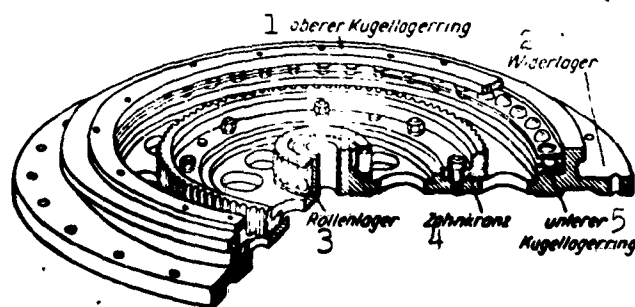
Fig. 9. Pivot ring of a weapon. 1)
Upper ball-bearing race; 2) support;
3) roller bearing; 4) gear rim; 5)
lower ball-bearing race.

leads. The motor and the equipment on the swivel portion are fed by
means of a sliding contact.

The platform for the weapon personnel is attached to the gun
mount (Fig. 8), and the aiming mechanisms, the sights, and the protec-
tive shields are also fastened to the mount. Moreover, the gun mount
carries the cradle frame with the trunnion bearings. In the case of
stabilized weapons, the stabilization axle is housed in the upper por-
tion of the fixed weapon base in order to permit the stabilization por-
tion of the weapon to move. The platform for the personnel and the pro-
tective shield or armor that is attached to the gun mount is known as

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the platform deck. The pivot ring (Fig. 9) serves as a step bearing for the gun mount and is rigidly connected to the body of the ship. The ball bearings of the pivot ring, together with the lower ball-bearing race, carry the weight of the weapon and the increasing vertical forces of the swiveling parts of the weapon. The roller bearing of the pivot journal, on the other hand, absorbs the horizontal forces. The pivot ring is provid.   _th a gear ring which meshes with the spur gear of the horizontal aiming mechanism, thus ensuring the horizontal aiming of the weapon.

We will subsequently become familiar with the major parts of the cradle and the gun mount. At the moment, we will deal with the barrel of the weapon (Fig. 1C). The desired direction of motion is imparted to the shell in the barrel and it is here that the shell also attains the required initial velocity and rotational motion. The bore is subdivided into the shell chamber, the forcing cone, and the rifled portion. The breech plate is screwed onto the rear part of the barrel. The forward end of the barrel is known as the muzzle. The barrel itself tapers from the breech plate to the muzzle. A pressure in excess of 3500 kg/cm^2 and high temperatures up to 3000°C may develop as the gun is fired, as a result of the combustion of the charge. The forces of the gases produced by the detonation of the charge act against the base of the shell and press the rotating bands of the sl..l into the grooves [rifling] of the barrel (raised bands between which the lands are found) thus imparting continuous rotational motion to the shell. The rotational motion is a result of the fact that the grooves [rifling] corresponding to a helical line with a pitch of 25 to 30 calibers (the distance between grooves) are cut into the walls of the barrel bore. With a barrel length of 55 to 70 caliber, the shell executes a 2- to 2.5-fold rotational motion. Since the shell moves only for sev-

eral thousandths of a second through the barrel, it exhibits several thousand revolutions per minute as it exits from the barrel. This high number of revolutions imparts the required stability during flight to the shell and promotes a significant rise in firing accuracy. As it leaves the barrel the shell exhibits a velocity in excess of 1000 meters per second, and this velocity is known as the muzzle velocity, denoted by V_0.
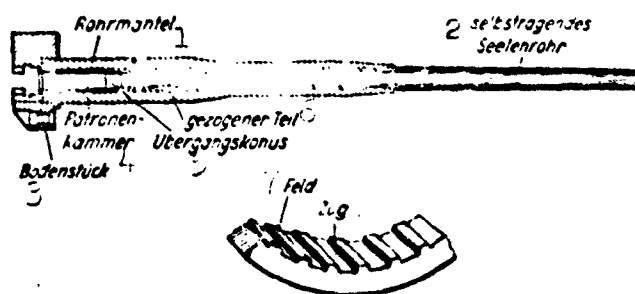
Fig. 10. Gun barrel with self-supporting liner. 1) Barrel jacket; 2) self-supporting liner; 3) breechplate; 4) shell chamber; 5) forcing cone; 6) rifled section; 7) land; 8) groove.

At the present time, in the majority of cases, anti-aircraft weapons are fitted out with monobloc gun barrels or barrels with a so-called free liner.

Monobloc gun barrels are of single-piece construction and represent nothing but a simple barrel with varying wall thickness. Barrels with free liners (Fig. 10) consist in the barrel jacket and a thin-walled (free) liner that is seated inside the barrel jacket. The jacket encases more than half of the liner and provides the required rigidity for the latter.

Modern barrels are fabricated of alloyed steels which exhibit outstanding properties, thus providing the required strength and ensuring great service life.

In order to take better advantage of the ballistic properties of
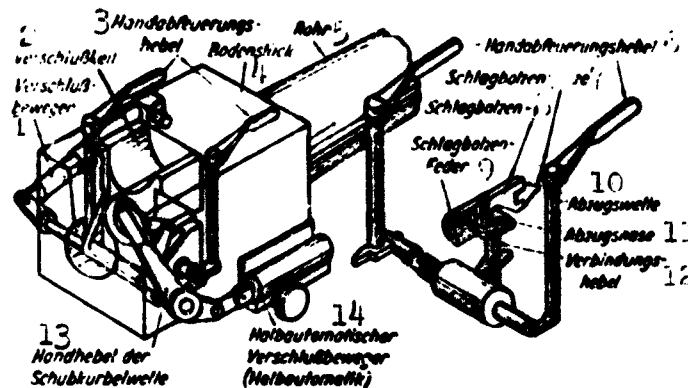
Fig. 11. Breech and breech mechanism. 1) Breech arm; 2) wedge-type breechblock; 3) manual firing lever; 4) breech; 5) barrel; 6) manual firing level; 7) striker; 8) firing pin; 9) firing-pin spring; 10) firing rod; 11) sear nose; 12) connecting lever; 13) lever of breech-mechanism crank; 14) semi-automatic sliding-wedge breech mechanism.

artillery weapons during firing and in order to raise the service life of a barrel, the gun barrels are cooled with seawater if they have become overheated as a result of firing. The cooling is accomplished with a cooling hose. One end of the hose is connected to the fire-extinguishing connection, the other end of the hose being led into the shell chamber. A cooling process lasting from 1.5 to 2 minutes is adequate to cool the sides of the barrel and again to undertake firing of the weapon at the maximum rate of fire.

The rear portion of the gun barrel is threaded to permit the screwing on of the breechplate (Figs. 10 and 11). This includes the breech mechanism. Moreover, the breech also contains the shell-casing ejectors, release mechanisms, and smoke discharge units.

The breech mechanism in the case of anti-aircraft weapons is in the shape of a wedge which at the instant of firing effects tight closure of the shell chamber. Depending on the direction of their motion in the breech, the wedge-type breechblocks are subdivided into horizontal and vertical categories. The frontal area of the wedge-type breechblock runs perpendicular to the barrel axis, whereas the rear area of the wedge-type breechblock does not run parallel to the frontal

area, but rather at a small angle to the latter. It is for this reason that we speak of a wedge. If the wedge-type breechblock in the breech is shifted in the direction of fire, then the rear area of the breechblock presses against the base of the breech and thus closes the shell chamber.

As the wedge-type breechblock is opened, the frontal area of the wedge moves away from the barrel walls. On the one hand, such a breech mechanism ensures the desired shell feed and on the other hand eliminates almost completely the frictional forces between the base of the shell casing and the frontal area of the wedge breechblock on opening. Wedge-type breechblocks are advantageously serviced and make it possible to automate the shell feed.

On firing, the shell casing is pressed by the exhaust gas against the walls of the [shell] chamber and the base of the casing is pressed against the wedge breechblock. The gases, thus, cannot pass between the walls of the casing and the chamber in the direction of the breech mechanism.

The discharge gases exert equal pressure in all directions. The radial pressure is exerted against the chamber walls, the longitudinal pressure is exerted on the one hand against the wedge breechblock, and on the other hand, against the base of the shell. The discharge gases overcome the resistance of the shell in the barrel and finally drive the latter through the barrel. The forces acting against the wedge breechblock as a result produce the recoil of the barrel.

In the case of turret and deck-turret weapons the opening of the wedge breechblock causes an air valve to open and air passes from the breech into the barrel in order to remove the gases produced by the explosion of the charge. If the barrel is closed off by the wedge breechblock, the supply of air is also interrupted.

If the weapon has been loaded, the wedge breechblock has to be moved by hand once. During firing, the wedge breechblock is moved automatically by means of the semi-automatic mechanism, during the course of the recoil.

The firing may be carried out mechanically or electrically. Mechanical firing is achieved through the actuation of appropriate foot-operated firing levers by the gun layers (Fig. 11). As the sear clears the firing pin, the latter drives forward because of the tension of the firing-pin spring and strikes against the threaded primer in the base of the shell, thus igniting the charge in the casing.

In addition to mechanical firing by means of a foot-operated firing lever, manual firing is also possible. The hand-operated firing lever is mounted at the breech ring. As a rule, manual firing is employed for the repeat firing of a shell in the event of a misfire.

In order to brake the recoil of the barrel and in order to attenuate the counterrecoil of the parts sliding back to their initial positions, provision is made for the so-called counterrecoil mechanism. The counterrecoil mechanism of medium-caliber weapons in general consists in a hydraulic brake and from one to two hydraulic recuperators. The hydraulic brake absorbs the energy of the backsliding parts on firing and in addition it brakes the counterrecoil. The recuperator [counterrecoil mechanism] serves to return the backsliding parts after firing to their initial positions.

Medium-caliber weapons are generally loaded by hand. On initial loading of the weapon, the gun loader must open the breech and heft the shell into the chamber. In the case of weapons in excess of 100 mm caliber, the shell weighs more than 30 kg. The loading procedure in the case of such weapons by hand is particularly difficult without some auxiliary devices.

To facilitate the operating conditions, these weapons are provided with mechanical shell-input devices.

The shell-loading device is fastened to the cradle and ensures reception of the shell and the input of the latter at all barrel elevations. In order to guide the shell without difficulty, it is placed in the loading tray. The gun loader then operates the loading lever, thus opening an air valve to permit the entry of compressed air into an operating cylinder. Depending on the elevation of the weapon, the variable quantity of air required for the shell feed streams into the operating cylinder. The air acts against a piston and sets the follower into motion by means of a cable drive; the follower then directs the shell into the chamber.

If for some reason the supply of air is not available, the follower can also be operated manually, although in this case speed is lost, and this leads to a lowering of the rate of fire.

Let us now make several comments regarding the aiming of weapons.

The aiming procedure involves the placement of the barrel in a given position in order to enable the shell to hit the target. Aiming is carried out by means of elevation and traversing mechanisms on the basis of vertical and horizontal data provided by the fire-control instrumentation. In the case of stabilised weapons, the trunnion axles are also aimed. If the aiming procedure is carried out in accordance with data transmitted from the computer center, we speak of centrally controlled aiming. If these data are derived through the sighting of the individual weapons, we speak of autonomous aiming.

The aiming procedure may be carried out manually or by means of an electric motor, semi-automatically or automatically. Automatic aiming is effected by means of a servomotor, without participation of the gun layers. In the case of semi-automatic aiming, the gun layer actu-

ates the drive according to data that are read off either from special pickups or provided through the sights.

The field of fire for any weapon can be restricted in order to prevent aiming at an unattainable sector. The vertical aiming mechanis is found on the left-hand side (Fig. 12). It consists of a hand drive and an electrical drive. The motion of the crank handle is transmitted to a spur gear which meshes with the toothed segment of the elevation mechanism that is connected to the cradle. Vertical aiming is carried out in accordance with data received from appropriate pickups or derived through the weapon sight. The horizontal aiming mechanism is
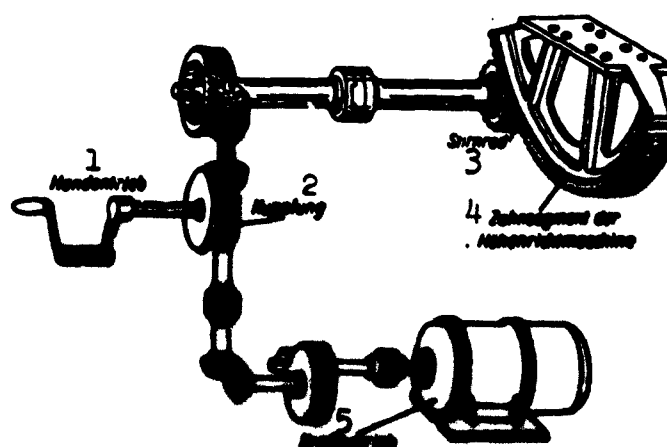
Fig. 12. Vertical aiming mechanism.
1) Hand drive; 2) coupling; 3) spur wheel; 4) toothed segment of elevation mechanism; 5) power drive.

found to the right of the weapon and it also consists of a hand drive and an electrical drive. The swiveling of the weapon is achieved through the motion of a gear wheel which meshes with the traversing rack of the base plate, so that the weapon moves along a horizontal line. The aiming procedure is carried out in accordance with data taken from a pickup unit for horizontal aiming or by means of the data derived through the sight of the weapon.

The trunnion axles are lined up only in the case of stabilized

weapons. A special sight may be employed to effect the stabilization, by having the gun layer line up the horizontal sighting line with the horizon, or on the basis of the data provided by a sensing element pickup to which data regarding the magnitude of roll are continuously being supplied.

Later on we will discuss the utilization of light-caliber weapons. These weapons are employed for operations against aerial targets at low altitudes (below 3500 meters). However, they can also be used against small surface-vessel targets and against visible coastal targets at short range.

The assignments which must be carried out are also decisive for the structural features of these weapons. The required density of fire demands that these weapons exhibit a high rate of fire — more than a hundred rounds per minute for each gun — and this calls for the automation of the over-all fire control. The great speeds of aerial targets call for great aiming speeds which for vertical and horizontal aiming must amount to 50 to 60° per second.

Light-caliber weapons are small in size and light in construction. For this reason, a considerable number of such weapons can be used aboard ships. These weapons are provided with sights which can be used against visible aerial, naval, and coastal targets.

Remote-controlled weapons can be used at all times under all weather conditions. To raise the density of fire, it has become the practice to develop weapons carrying several guns.

Light-caliber weapons exhibit all of the important structural elements with which we are familiar from the medium-caliber weapons, and we have reference here to the cradle, the gun mount, and the base plate. For this reason, we will consider only several of the structural features of the cradle part and the sighting mechanism of the 37-mm

automatic weapon.

The cradle portion of this automatic weapon carries the entire gun. The barrel housing of the cradle portion guides the barrel on counterrecoil and recoil. The recoil brake is situated beneath the barrel housing (Fig. 13). A heavy counterrecoil spring serves as the recuperator, and this piece is seated on the barrel. The cradle part is seated in the trunnion bearings of the gun mount. The elevation-drive toothed segment, meshing with the spur wheel of the elevation mechanism, is fastened to the underportion of the cradle.
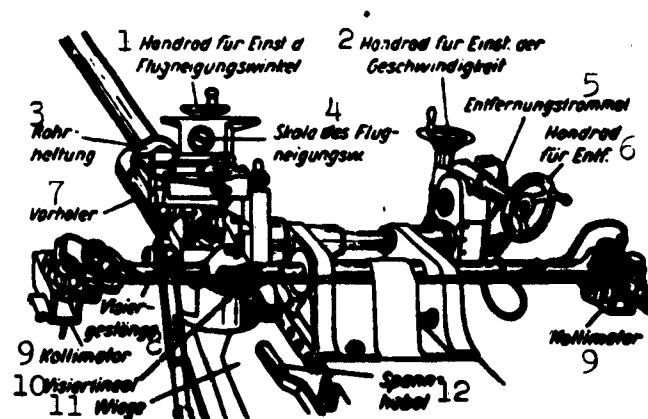
Fig. 13. Aiming mechanism of 37-mm weapon. 1) Hand wheel for setting of dive angle; 2) hand wheel for setting of speed; 3) barrel bracket; 4) dive-angle scale; 5) range knob; 6) range-finder drum; 6) hand wheel for range finder; 7) recuperator; 8) sight parallelogram linkage system; 9) collimator; 10) sighting line; 11) cradle; 12) cocking lever.

The automatic weapon generally is fitted out with a wedge-type breechblock which can move vertically. The shell feed and follower unit are part of the automatic loading mechanism. The design of the breechblock and the a..tomatic loading mechanism ensure the automatic opening of the breechblock after firing, the extraction of the casing from the shell chamber, the cocking of the firing pin, the feeding of the following shell onto the loading tray, the insertion of the shell into the chamber, the closing of the breechblock, and finally the firing. The automated aspects of this procedure relate to the exploitation

of the reaction forces produced by the gases evolved through the detonation of the charge.

On initial loading, the breechblock must be opened manually with a cocking lever which is mounted on the left-hand side of the cradle (Fig. 13). The design of the 37-mm automatic weapon permits single-round and automatic firing. The shells are automatically carried to the loading tray and it is possible to continue firing without interruption, given a continuous supply of ammunition, until the barrel reaches the maximum permissible temperature; at this point, firing must cease and the barrel must be given a chance to cool. Various gun barrels have been fitted out with cooling jackets through which sea water from the fire-extinguishing system is made to flow, the barrel thus being continuously cooled. Light-caliber weapons are provided with automatic or front ring sights which make possible operations against aerial, water, and coastal targets.

Figure 13 shows the automatic sighting unit of a 37-mm automatic weapon. This weapon has been fitted out with a double-sided sight. On the left-hand side of the weapon we find the computer element of the sight and the collimator for the vertical sighting operation; on the other hand, on the right-hand side of the weapon we find that part of the sight that is employed for the setting of target range and target speed, as well as the collimator for horizontal aiming.

The collimators are connected to one another by means of the sight parallelogram linkage system and they are arranged so that the sighting line of each collimator is parallel to the sight linear setting whose position relative to the axis of the barrel is governed by the angle of elevation and the lateral lead. If the sighting line of the collimator is aligned with the target, the barrel points in the direction of the required set-forward point. The gun layer sitting on the right-

hand side of the weapon actuates the horizontal aiming drive until the vertical filament of the crosshairs lines up with the target, and it is his responsibility to see that this position is maintained; the gun layer sitting on the left-hand side of the weapon, on the other hand, actuates the vertical aiming drive until the horizontal filament of the collimator lines up with the target.

The left-hand gun layer must set the sight parallel to the heading of the target, whereas the gunner on the right-hand side of the weapon is responsible for the setting of the range and target velocity. The hand wheels intended for this purpose can be seen in Fig. 13. When both gunners have lined the center of the crosshairs up with the target, fire is opened.

Front ring sights differ from automatic sights in their simple design. A smaller staff is required to service this type of sight, although the accuracy here is lower than in the case of automatic sights, and in practical terms the time required to train the gun layers is considerably longer. The sight consists of a number of concentric rings that are connected to one another by means of crosshairs. The sight is positioned in front of the gun layer. The outer ring in general corresponds to a target velocity of 300 meters per second, the remaining rings being intended for velocities of 200, 100, and 50 meters per second. From the center of the sight the rings are numbered from 1 to 4, so that the fourth ring is the one on the outside.

The sighting ring required for purposes of firing the weapon is determined by multiplying the target velocity by the perspective foreshortening. In this case perspective foreshortening refers to the ratio of the apparent aircraft dimensions to the actual dimensions (1/4, 2/4, 3/4, 4/4). The resulting quantity is then rounded off to the value of the closest velocity ring.

The gunner sights the target with the velocity ring, determined by calculation, and then opens fire. The center of the front ring sight is used to fire at divebombers engaged in a direct attack against the ship. Remote-controlled weapons are set automatically on the basis of data supplied by the fire-control equipment.

The machine guns mounted in boats are also important since they exhibit a high rate of fire and are capable of operations against targets at heights up to 1500 meters. In order to increase density of fire a number of such weapons are combined in a single unit. Moreover, machine guns can also be employed successfully against water and coastal targets.

Machine guns are simple in construction and are easily serviced. They are light [in weight] and do not take up too much space; therefore, this type of weapon is commonly employed aboard boats and civilian vehicles in the event of war.

Machine guns can be equipped with front ring sights or with automatic sights that differ but slightly in design from the sights already considered.

During the war machine guns were successfully used for operations against aerial targets and quite a number of aircraft were put out of operation by these weapons.

AMMUNITION

Firing success depends in great measure on the quality of the ammunition. The most modern weapon loses in combat effectiveness when the available ammunition is worthless. Basically, ships and boats are stocked with a definite quantity of ammunition for each gun. The total quantity of ammunition aboard a vessel is known as the on-board stores.

In view of the fact that naval weapons are employed for a variety of purposes, the ammunition stores must be suitable for operations
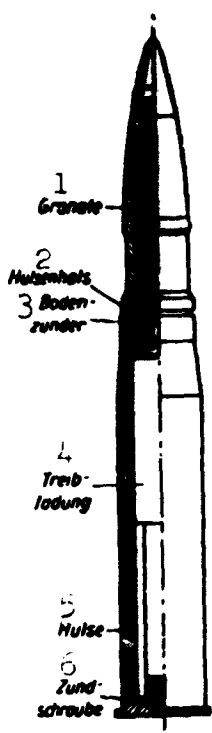
Fig. 14. Fixed-
ammunition
shell. 1) Shell;
2) casing neck;
3) base deton-
ating fuse; 4)
charge; 5) cas-
ing; 6) threaded
primer.

against aerial, water, and coastal targets. For
this reason the ammunition stores are made up of
various types of ammunition.

Thus fragmentation shells with time fuses
are used for operations against aerial targets.
The time fuse is intended to produce a large quan-
tity of fragments upon the explosion of the shell.
Against water and coastal targets, on the other
hand, high-explosive and combined high-explosive
fragmentation shells with impact fuses are used.
Armor-piercing shells have stable shell casings
and are used against armored targets because
these shells can destroy obstacles easily or
pierce them.

Light-caliber weapons fire fragmentation in-
cendiary shells with impact fuses and armor-
piercing shells with base detonating fuses, i.e.,
armor-piercing solid-body shells. In order to fa-
cilitate observation of shell trajectories and to implement firing cor-
rections, the shells are provided with a tracer composition that is ig-
nited by the propellant charge.

A shell consists of the following:

● a fuse,

● the round and

● the casing.

Depending on the caliber, we distinguish shells (fixed ammunition)
and separate cartridge ammunition. In the case of the fixed shell, the
round is directly connected to the casing carrying the propellant
charge, and it forms a single piece (Fig. 14). In the case of separated
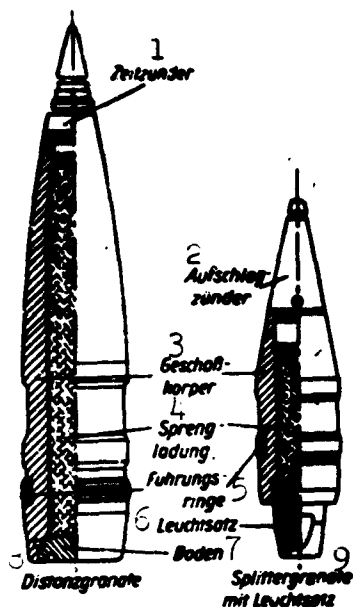
Fig. 15. Anti-aircraft shells. 1) Time fuse; 2) impact fuse; 3) casing of round; 4) demolition charge; 5) rotating bands; 6) tracer composition; 7) base; 8) long-range shell; 9) fragmentation shell with tracer composition.

cartridge ammunition, the cartridge casing is stored separately from the round.

Since we are considering air defense, we will consider the fragmentation shells with time fuses in greater detail, because these are frequently also classified as long-range shells (Fig. 15). This particular type of snell is designed to take aerial targets out of operation as a result of its fragmentation effect and for this reason the shell must be designed to produce as great a quantity of effective fragments on detonation as possible.

A fragment capable of penetration is one which weighs no less than 5 g. The quantity of fragments depends on the material, on the thickness of the walls of the round, and on the weight of the detonation charge.

The walls of the round generally exhibit a thickness amounting approximately to 1/4 to 1/6 of the caliber, while the weight of the detonation charge amounts approximately to 10 percent of the weight of the round. With such a ratio between the weight of the detonation charge and the thickness of the walls of the round a maximum quantity of fragments capable of penetration is guaranteed.

Thus on the detonation of a medium-caliber round several hundred fragments capable of penetration are formed. On explosion, approximately 20 percent of the fragments are formed by the nose section of the shell, up to 70 percent come from the side walls, and up to 10 percent are formed from the base.

The fragmentation effect is characterized by the distance from the

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point of detonation at which the fragments still retain their penetrating power. This distance is a function of fragment velocity imparted to the fragments by the detonation and it is also a function of fragment weight.

The fuse designed to detonate the detonation charge is screwed into the nose section of the shell. Fuses are divided on the basis of operating principle into impact fuses and time fuses.

Impact fuses are employed for light-caliber shells, whereas time fuses are used in medium-caliber shells. The basic parts of a fuse include the following:

- the fuse body,
- the impact device,
- the detonator,
- the blasting cap,
- detonator cap, and
- the arming pin.

It is the function of the arming pin to prevent the accidental detonation of the shell during transport and in storage. Moreover, the arming pin ensures bore safety. The detonator serves as a primer charge and is used to detonate the detonation charge. The detonator itself is fired by means of a detonator cap. The detonator is positioned between the detonator cap and the detonation charge and serves to ensure complete detonation of the charge.

After the firing pin has struck the detonator cap, the detonation proceeds in the following sequence: detonator cap, blasting cap, detonator, detonation charge.

Modern fuses are extremely complicated in construction and exact in their operation; however, the success of the firing depends on their proper functioning. The 37-mm fragmentation shell with tracer composi-

tion is fitted out with a point-detonating fuse, and with a self-destroying fuse which explodes the shell after a certain lapse of time, should the shell have failed to hit the target.

If such a shell strikes a target, the detonation cap is fired and the detonation process continues in sequence to the detonator and the detonation charge. If the shell misses the target, it is exploded by means of the self-destroying fuse after the burning time of the latter has elapsed.

Time fuses are again subdivided into powder fuses and mechanical fuses. In powder time fuses three time-train rings are positioned between the detonator cap and the blasting cap. These time-train rings have powder-filled bores and are in communication through connecting orifices that are designed to permit the passage of the flame. It is the purpose of these rings to prolong the detonation process. The powder-filled bore burns for a definite period of time. The time-train rings can be turned with respect to one another by means of a fuse-setting key designed especially for this purpose. When this is done the positions of the connecting orifices are altered with respect to one another, and this makes it possible either to prolong or shorten the burning time of the powder.

By altering the duration of the powder burning time, the distance to the point of detonation is also altered. Thus the flames on the one hand ensure that the detonation actually takes place and on the other hand make certain that the projectile [shell] covers a certain given distance in order to detonate at the predetermined point along the trajectory. The firing of the detonator cap is achieved in the barrel by the firing pin which is positioned in front of the detonator cap. After the firing the firing pin drives through the detonator-cap cover. The detonator cap then ignites the powder of the upper time-train ring.
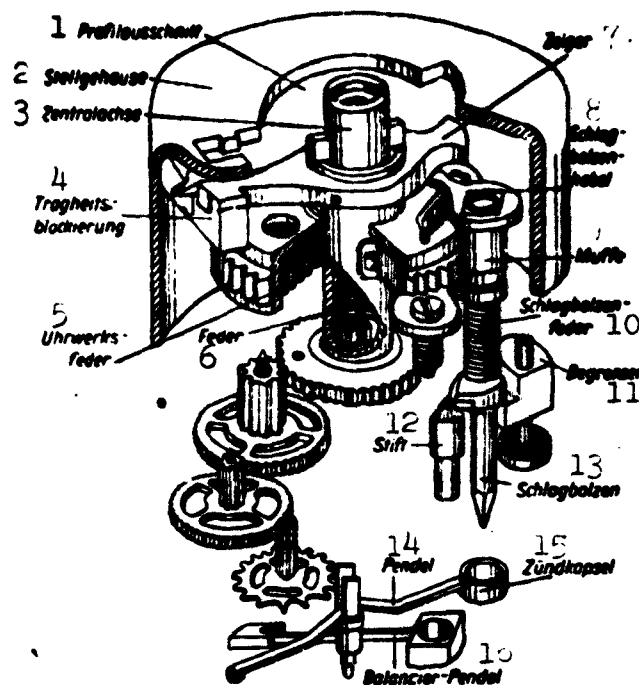
Fig. 16. Clockwork of time fuse. 1) Profile aperture; 2) housing; 3) center shaft; 4) inertia block; 5) clockwork spring; 6) spring; 7) pointer; 8) firing-pin lever; 9) coupling; 10) firing-pin spring; 11) limiter; 12) pin; 13) firing pin; 14) pendulum; 15) detonator cap; 16) balance pendulum.

After the powder of the upper time-train ring has been consumed, the powder of the middle time-train ring is ignited, followed by the powder of the lower time-train ring. If the total powder charge has been consumed in accordance with the setting, the flame of the lower time-train ring comes into contact with the blasting cap and the fuse has fulfilled its function.

The lower time-train ring is graduated to indicate a definite burning time for the powder charge. The fuse body carries a red graduation marking to permit setting.

Mechanical fuses are basically unlike the powder fuses, because their operational principle is based on the functioning of a clockwork mechanism (Fig. 16). Mechanical fuses are more modern and exact in effect than are the powder fuses.

The time of detonation for a projectile at the given point along

the trajectory is given by the previously set clockwork mechanism of the fuse. All elements of the fuse circuit, the detonator cap, the blasting cap, and the detonator are positioned beneath the clockwork mechanism in a mechanical fuse. In order to permit the setting of the detonation time, such a fuse is also provided with a time-train ring that is to be turned through a corresponding magnitude. The housing with its profile aperture is turned according to a pointer simultaneously with the time-train ring. On firing, the pointer is released from the inertia block and the clockwork mechanism begins to function; the central shaft together with the pointer is set into uniform motion by the force of the clockwork-mechanism spring. The uniform rotation is ensured by a balancing pendulum. The pointer which is carried in the upper part of the housing continues to turn as long as it is aligned with the profile aperture. In this position it is pressed through the profile aperture by the pressure exerted by the spring. The firing-pin lever which blocks the firing pin is thus released.

The firing pin is actuated by the firing-pin spring to strike the detonating cap which then fires the blasting cap and the detonator. Thus the firing of the detonating cap does not occur at the instant of firing as was the case with the powder fuse, but after a definite lapse of clockwork operating time.

The fuse time-train ring is calibrated to correspond to a definite operating time of the fuse (Fig. 17). The setting of the fuse is carried out relative to a permanent graduation marking on the fuse housing. A hand fuse setter is used to effect the setting and this setter is employed to turn the tension ring [time-train ring] through the corresponding value (Fig. 17). The setting carried out by means of the hand fuse setter is, however, not accurate enough and calls for considerable skill on the part of the individual responsible for setting
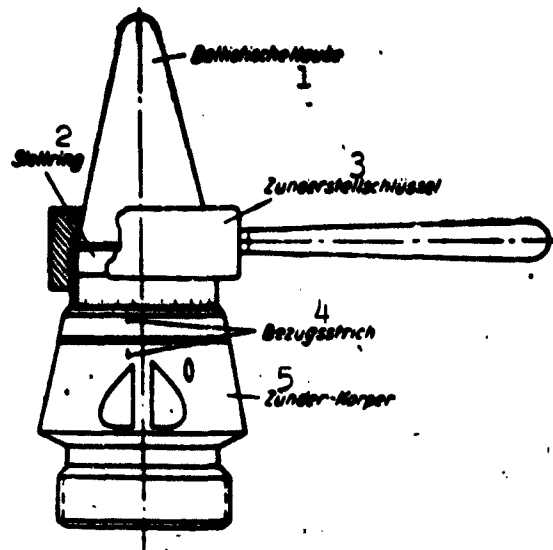
Fig. 17. Fuse setting with hand
fuse setter. 1) Ballistic cover;
2) tension ring [time-train ring];
3) hand fuse setter; 4) reference
graduation; 5) fuse body.

the fuse, and particularly in the case of motion at sea leads to con-
siderable error.

In order to improve the working conditions of the individuals r -
sponsible for setting fuses and to raise accuracy in fuse setting,
weapons today are fitted out with fuse-setter equipment.

At the start of the second World War, radar fuses were developed
for the navies.

Aiming errors and time-fuse setting errors lead to a situation in
which the point of detonation is not always reached in the immediate
vicinity of the target, and so the target is not always seriously dam-
aged. For this reason a large quantity of ammunition was needed for
the destruction of aerial targets. The radar fuse (Fig. 18) requires
no advance fuse setting, but takes over automatically in the vicinity
of the target, at which point the shell is capable of inflicting the
greatect damage to the target.

In the opinion of foreign specialists the radar fuse should be re

garded as the most modern fuse at the present time and it is therefore finding ever-greater application, it is continuously being refined, and is also being employed in rockets and in bombs.

The operating principle of a radar fuse is similar to that of a radar station (Fig. 19). A transmitter and a receiver are built into the fuse body. Moreover, the fuse is fitted out with an antenna that is intended for transmission and reception. After firing, the power source is actuated and provides for the emission of electromagnetic waves into space. An electromagnetic field is formed around the fuse 'Fig. 19'. If this field comes into contact with a target, the signal reflected from the target is picked up by the receiver in the fuse and converted into electrical pulses which are amplified in proportion to the approach to the target.

If the fuse is some 30 to 50 meters from the target, the fuse is actuated by the amplified pulses. In the following the reader will be familiarized with the construction and operating method of a British radar fuse.

A radar fuse is small in size and resembles a mechanical time fuse. The individual parts of the fuse are housed in a steel cylinder known as the fuse body which is covered with a plastic dome (Fig. 18). The most important parts of the radar fuse include the following:
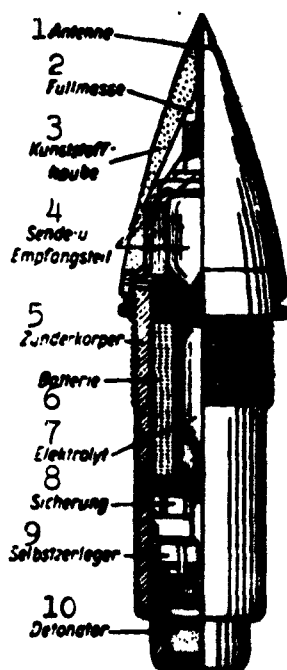

Fig. 18. Schematic diagram of radar fuse. 1) Antenna; 2) filler; 3) plastic cover; 4) transmit-receive unit; 5) fuse body; 6) battery; 7) electrolyte; 8) safety device; 9) self-destroying fuse; 10) detonator.

● the detonation mechanism and the

● transmit-receive unit.

The detonation mechanism produces the detonation of the shell

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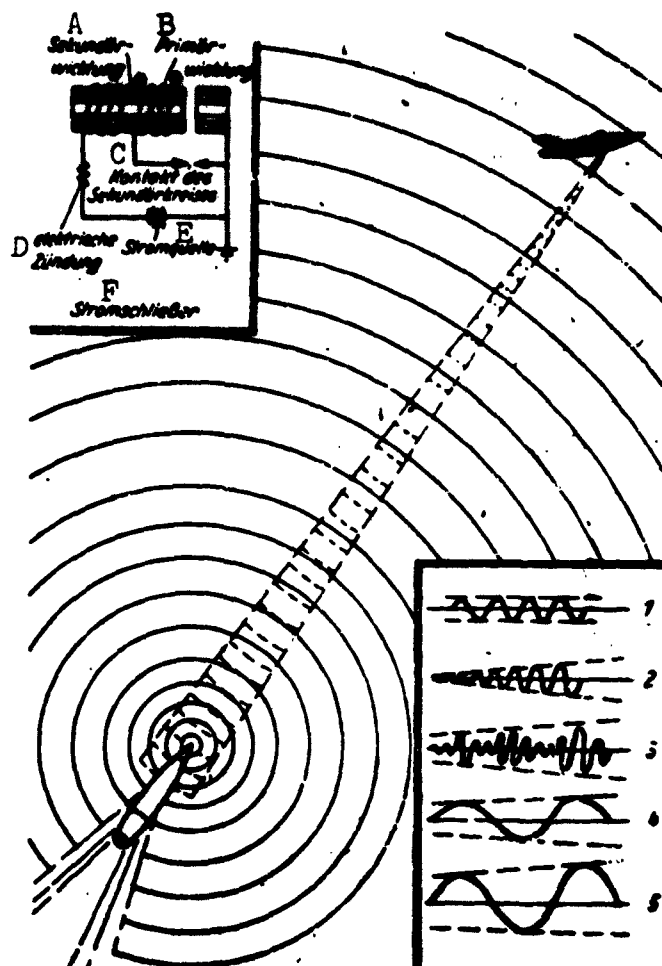
Fig. 19. Operating principle of radar fuse. 1) Signal from fuse antenna; 2) target-reflected signal; 3) signal oscillation (receiver input); 4) audio frequency (receiver output); 5) amplified signal for primary winding of contact. A) Secondary winding; B) primary winding; C) contact of secondary circuit; D) electrical detonation; E) current source; F) contact.

charge at the given time. This mechanism includes an electrical primer, the blasting cap, and the detonator.

The transmit-receive unit of the radar fuse includes a current source, the transmitter, the receiver, and a contact pore.

The electrical primer, the blasting cap, and the detonator are positioned in line in the bottom part of the fuse body. The electrical detonation is ensured by means of a resistance bridge jacketed with black powder. The resistance bridge consists of a special wire exhibiting high electrical resistance. A detonation initiator is employed as

the blasting cap. The blasting cap is set off electrically. The de-
tonator is used to amplify the effect of the blasting cap. In order to
set off the detonation, the electric current must be passed through
the resistance bridge, the bridge must be made to glow, and thus to
cause the black powder to burst into flame. The resulting flame then
ignites the blasting cap.

In order to cause the resistance bridge to begin to glow at the
given instant of time, a special contactor is employed.

Among others, this contactor includes an electromagnet relay that
is connected to 2 circuits. The first circuit, as a rule, is known as
the control circuit, while the second circuit is known as the working
circuit (Fig. 19). The power source, the secondary winding of the elec-
tromagnet, and the electrical ignition are series connected in the
second circuit. If a voltage of specific magnitude is applied at the
first winding of the electromagnet, the armature is attracted and the
contacts of the second circuit are closed. Thus the flow of current
through the secondary winding is ensured and nothing stands in the way
of the ignition.

The transmit-receive unit of the fuse, in conjunction with the
amplifier, provides the input voltage for the contactor at the required
instant of time. The transmit-receive unit, the amplifier, and the an-
tenna are mounted in the nose section of the fuse.

The high-frequency electromagnetic waves emitted by the transmit-
ter into space are simultaneously picked up by the receiver, although
the electromagnet of the contactor is not affected by this. If, how-
ever, targets should appear within the effective range of the fuse,
the emitted waves ar reflected from the surface of the target and thes
are picked up by the fuse antenna.

Inasmuch as the respective positions of fuse and target are chang-

ing relative to one another, the reflected signal naturally exhibits higher frequency than the emitted signal (the Doppler effect). The i flected signal is weaker than the emitted signs , although with clos distance the signal is amplified.

Both signals are added in the antenna and so-called beats apper i.e., oscillations of an intermediate frequency with periodically f. tuating amplitudes. If the beats reach the receiver, the low-frequei. oscillations are isolated by the receiver, amplified, and carried to the contactor. The low-frequency alternating-current voltage applied to the contactor increases as the distance between the shell and the target diminishes and finally detonates the fuse when the voltage a tains a given value.

Dry cells are used as the power source in radar fuses. The eic trodes are connected to a block and — insulated from the housing — into the fuse.

The electrolyte is carried in a glass ampule that is stored in center of the electrode block. The mounting of the glass ampule permits limited axial shifting. A firing pin is built into the fuse and is situated beneath the glass ampule. The ampule is protected agains accidental destruction by a spring which maintains the required distance between the base of the ampule and the tip of the firing pin. As the shell leaves the barrel, the ampule overcomes the resistance of the spring by inertial forces and is demolished as a result of strong impact against the tip of the firing pin. The electrolyte flows over the electrode block to produce an element that provides the required current to supply the transmit-receive unit.

Radar fuses are, in addition to the above-considered parts. also equipped with self-destroying fuses which are actuated if the fuse fails to detonate in the proximity of the target; in addition, radar

fuses incorporate a safety device which eliminates the possibility of accidental fuse activation prior to firing.

FIRE-CONTROL EQUIPMENT

Firing against aerial targets differs significantly from the organization and theoretical execution of firing against water and coastal targets.

Aerial targets fly at great velocities, are small in size, and remain only for brief periods of time in the firing zone. These features make operations against aerial targets more difficult and affec' the design of the fire-control equipment, as well as   methods and operations of anti-aircraft artillery.

Operations against aerial targets call for exact knowledge of lav' governing target and projectile motion.

As is well known, a projectile does not fly a straight line, bu· rather describes a curved trajectory. This trajectory consists of an ascending branch which reaches to the peak of the trajectory, and of a descending branch which concludes with projectile impact. For firing against aerial targets only the ascending branch of the trajectory is significant, so that the time fuses intended for operations against aerial targets are designed and constructed exclusively for this portion of the trajectory.

We will subsequently deal with the elements of the trajectory in a rectangular coordinate system which does not take rolling motion into consideration (Fig. 20). The line OZ connecting the weapon and the target is known as the slant range. The angle ε between the line OZ and the horizor is known as the target elevation angle.

Since the projectile does not move in a straight line, but rather over a curved trajectory which passes through the target, additional elevation of the gun barrel is required and this must correspond to the

magnitude of the angle of target elevation. This additional elevation
is a function of firing range. The angles through which the barrel of
the weapon must additionally be raised are known as the elevation cor-
rection. The sum of the target elevation angle ε and the elevation cc,
rection α is denoted as the elevation angle φ. In order to hit the tar
get, the barrel of the weapon must be raised through this angle from
the horizontal position. On firing the barrel elevated through the
angle φ is forced out of its initial position as a result of the de-
veloped forces. The resulting angle ω is known as the angle of jump.
The sum of φ and ω accordingly forms the quadrant angle of departure
at which the projectile leaves the barrel on firing.
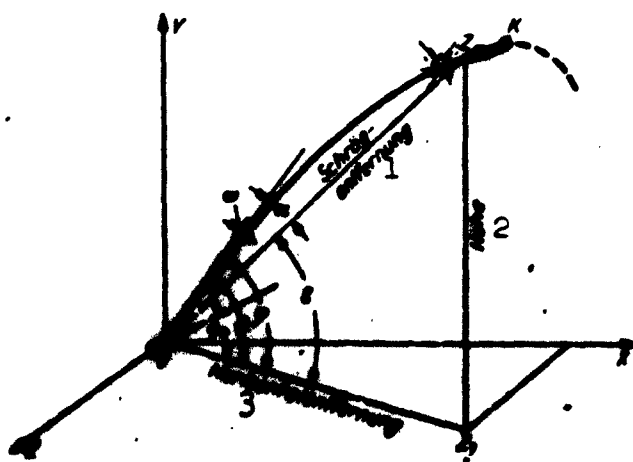
Fig. 20. Projectile trajectory and
its elements. 1) Slant range; 2) al-
titude; 3) horizontal range.

On ships the sweep zone of anti-aircraft weapons is restricted in
the horizontal plane by the superstructures of the ships and in the
vertical plane primarily by the design of the weapon itself. As a rule,
the maximum barrel elevation amounts to 85°. The zone formed by the
ascending trajectory branches in the sweep zone is known as the zone
of range limits. This zone is shown in Fig. 21, no horizontal limita-
tions having been taken into consideration here.

The zone of range limits for anti-aircraft weapons can be repre-
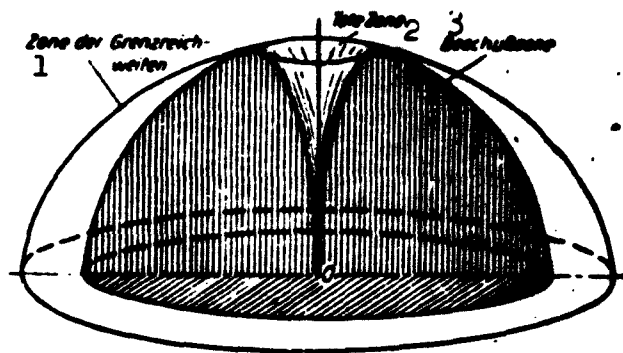
Fig. 21. Zone of range limits and
effective zone. 1) Zone of range
limit; 2) dead zone; 3) effective
zone.

sented in three-dimensional form, and the ascending branches of the

trajectory can be rotated 360° about the vertical axis which can be

imagined to pass through the weapon. The surface formed as a result

forms the extreme limit of the space. The inside space limit is pro-

duced by the rotation of the ascending branch of the trajectory through

the above-mentioned vertical axis with a barrel elevation of 85°. The

volume element about the vertical axis — this element bounded by the

inside space limit — is known as the dead zone. It is impossible to

fire at targets in this zone. The firing zone lies within the region

of the zone of range limit; the firing zone refers to the space in

which the points of detonation for projectiles equipped with time fuses

may be found. In terms of dimensions the firing zone is smaller than

the zone of range limit.

Thus we have established that there exists for every anti-aircraft

weapon a limited zone within which it is possible to fire at aerial

targets. In order to hit the target, the barrel must be aimed in both

the vertical and the horizontal planes.

The horizontal sighting angle is comprised of the actual heading

angle q_m, the lateral deflection of the target, the motion of the fir-

ing ship during the period of projectile flight, and from a number of

corrections that are functions of the meteorological and sea-motion conditions. The vertical sighting angle consists of the firing range and a number of corrections which must be converted into angular quantities. The correction for range takes into consideration the variat'ᴄ in range during the period of projectile flight, the diminution of air density, the reduction in the initial velocity of the projectile, the effect of roll, and that of other magnitudes.

Through consideration of all corrections the sighting angles are divided into total horizontal and total vertical sighting angles (th' angles were earlier denoted as elevation and traverse quantities). For operations against aerial targets the weapons must be aimed in accordance with these total sighting angles. These angles are derived by means of the fire-control equipment.

Modern fire-control equipment consists of a large number of computers whose operation is rigorously dependent on one another. This equipment functions in conjunction with the technical observation facilities and is connected through remote-control systems to the required combat-control and weapon positions. The equipment at a fire-control installation is distributed on the basis of the purpose for which it is intended over a wide range of combat stations.

Synchro and follow-up systems are used for the transmission of the various values from the technical observation stations and command posts to the computers and for the remote control of equipment and machinery.

The synchro systems ensure the temporary coincidence of angular deflections on the part of several shafts that are not mechanically connected, and also the transmission of values to the equipment.

Since the operational accuracy of the synchro systems is a function of the load applied to the corresponding receiver, the latter can-

not, in practical terms, be loaded.

Follow-up systems which produce an adequate moment of rotation at the shaft of a vertical gyro are used for the automatic introduction of quantities to the equipment or machinery. The follow-up systems ca:;, for this reason, also be regarded as moment amplifiers.

The follow-up systems are subdivided into induction follow-up and contact follow-up systems.

In the case of an induction follow-up system the selsyn converts the magnitude of the angle into an electrical signal and transmits th:.. to the pickup electrically connected to it. The pickup controls a vertical gyro upon receipt of the electrical signals through an amplifi:?" The vertical gyro is intended to work out the quantities defined by the pickup and automatically provides for the input of the values to be transmitted into the corresponding equipment. The amplifier is designed to intensify the electrical signal of the pickup, this signal having the function of controlling the operation of the vertical gyro.

The contact follow-up systems are intended for the synchronization of the positions of mechanically unconnected shafts. The follow-up systems control the vertical gyro by means of a contactor.

The contact follow-up systems do not turn the shaft of the selsyn and the vertical gyro synchronously. The synchronization of the selsyn and vertical-gyro shafts occurs only after completion of the rotation. The contact follow-up systems become synchronized only after the position of the control element has been completely transmitted.

On the other hand, the induction follow-up systems transmit the values to be transmitted synchronously and in essence are thus similar to a synchro system.

The fire-control systems can be subdivided into automatic and simplified systems.

Automatic fire-control systems calculate the data required to hit the target on the basis of information received from the observation stations, all meteorological and ballistic corrections taken into consideration here. The simplified systems on the other hand take into consideration only a portion of the corrections and in part operate on the basis of estimated initial values.

The following major pieces of equipment are part of an automatic system:

● the circular-scan direction-finder station which is simultaneously employed for target allocation;

● the artillery radar station which supplies the initial data for the computer;

● the computer which is employed to solve the target firing problem;

● the remote-control mechanism for the automatic aiming of the weapon;

● the firing circuit and a number of auxiliary instruments.

Observation and Target-Indication Instruments

Radar stations at the present time represent the chief forms of observation and target-indication equipment. Optical instruments today fall into the category of reserve.

Radar stations can provide circular scanning for prolonged periods of time and can detect and recognize fast-moving targets within a range of several hundred kilometers, regardless of the meteorological conditions. The effective range with respect to low-flying targets, however, is limited by the immediate range of visibility. Radar stations which are employed for target indication in addition to observation transmit electrically the position of the detected target to the artillery radar stations which, after receipt of the target indication track the momen-

tary actual target and emit the target coordinates with a high degree of accuracy.

Daughter instruments (oscilloscopes showing data from a distant radar unit), connected to radar observation stations, are set up at command posts and important combat-operations headquarters. Thus the individual in charge of fire control or the commander is in a position to evaluate the air situation on the basis of the radar picture.

The main elements of a radar station include the following:

● the transmitter, with antenna;

● the transmit-receive switch;

● receiver unit with oscilloscope.

The transmitter and the receiver operate with the same antenna. A transmit-receive switch can be used to connect either the transmitter or the receiver to the antenna. Lumped electromagnetic waves are emitted by the transmitter and these, after striking the surface of a target, are reflected and again picked up by tne receiver.

A radar station seeks a target in a manner similar to that of a searchlight. Since the direction of the beam is established, the bearing and target elevation can be determined.

Since the velocity of propagation for electromagnetic waves is known to us ($v = 300,000$ km/sec) as well as the time (t) to the return of the emitted signal, we can easily determine the range to the target by multiplying v and t. The product of these quantities must, however, be halved in the determination of target range, since in the time t the signal covers the distance to the target and then returns to the ship. The range to the target is thus determined according to the following formula: $D_z = 1/2 v \cdot t$.

The propagation velocity of electromagnetic waves is great and therefore the time to the reception of the signal reflected from the

target involves only tenths or hundredths of a second. For this reason the process of antenna switching from reception to transmission and vice versa must proceed in millionths of a second.

Through the continuous switching on and off of the transmitter, reflected signals are constantly being received. The small time differ ences are naturally beyond the range of simple measuring devices and oscilloscopes must therefore be employed for this purpose (Fig. 22).
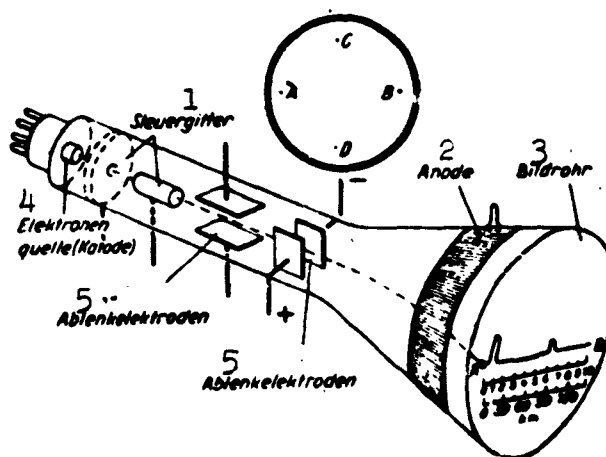
Fig. 22. Oscilloscope. 1) Control grid; 2) anode; 3) oscilloscope; 4) electron source (cathode); 5) deflecting electrodes.

The electron beam represents nothing but a beam of electrons moving from the cathode to the anode. The inside front wall of the oscilloscope is coated with a material that glows at the point struck by an electron beam. This electron beam can be controlled so as to be deflected either to the right or to the left, or it may be deflected up or down. A pair of vertical and horizontal deflecting electrodes is used for this purpose. The operating principle of these deflecting electrodes is based on the fact that the electrons are attracted to positively charged plates and repulsed by negatively charged plates. For example, if the left vertical plate is positively charged and the right vertical plate negatively charged, the electrons are attracted

to the left plate and the electron beam passing between the plates is deflected from its initial position to position A. If the plates are oppositely charged, the electron beam is deflected to position B.

Analogously, the electron beam can be affected by horizontal plates so that given appropriate charges the electron beam can be deflected to position C or position D (Fig. 22).

The charge on the vertical plates can be acted upon so that a glowing horizontal line AB is attained. If the length of this line is 10 cm and a thousandth of a second is required to cover this distance, the scale for the determination of the time at which the reflected signal is to return can be determined.

As the receiver picks up the reflected signals it charges the upper horizontal plate positively, causing the electron beam to deflect upward and this deflection becomes visible on the scope. The pulse emission is tuned to the horizontal motion of the electron beam so that the pulse is emitted from the transmitter at the instant of time at which the electron beam has attained its extreme position, i.e., at the time at which the glowing spot is opposite the zero indication.

The reflected signals are picked up by the receiver at brief time intervals and a continuous field of deflections is formed on the scope, with the last deflection being most clearly recognizable. As the reception time for the reflected signals changes, a corresponding change in the position of the deflection can be seen on the oscilloscope.

The deflection can be used to determine the time required for the reflected signal to complete the return, and thus it becomes possible by means of the above-cited formula to calculate the distance to the target. The calculation of the elapsed time is, however, inefficient and consumes considerable time. For the more rapid determination of target range, a range scale which takes the determined scale into con-

sideration is marked directly on the oscilloscope, rather than time markings.

Let the prominent indication on the oscilloscope correspond to a tenth of a millisecond. Which range will, in this case, correspond to this time period? This can be calculated as follows:

$$D_2 = \frac{300\,000 \cdot t}{2} = \frac{300\,000 \cdot 0,0001}{2} = 15 \text{ km.}$$

In other words, an over-all measuring range for one millisecond corresponds to an over-all range of 150 km.

After the calculated values have been marked on the scope, it becomes possible to read off the target range without any further computation (Fig. 22).

If not just one but several targets are located in the direction in which the beam is radiated, each target forms its own reflected pulse and the corresponding deflections appear on the scope.

Optical instruments such as target-indication sights and range finders are used in addition to radar stations for purposes of detection and target indication.

Artillery Radar Stations

Stabilized fire-control stations are employed for purposes of detection and the transmission of target coordinates. It is the function of the fire-control stations to track the target continuously, to determine the coordinates constantly, and to transmit these coordinates to the computer center for purposes of enabling the latter to resolve the target firing problem.

Instruments for Computation of Initial Firing Data

The most important instruments designed for the computation of initial firing data are housed at the computer center and include the computer, the coordinate converter, the fire-control equipment, the

firing circuit, and others. Of the above-enumerated instruments, the computer is the most important. This unit solves the firing problems relative to aerial, water, and coastal targets and determines the settings for the weapons, without taking roll into consideration. In addition, the computer provides the fuse setting for firing against aerial targets.

The coordinate converter transforms the computer-derived firing angles into total firing angles for which roll has been taken into consideration, and these are subsequently transmitted to the weapons. The determination of the firing angles in the computer and in the coordinate converter is a continuous and automatic process.

Laying Mechanisms

Naval weapons are fitted out with instruments and mechanisms which can be employed for purposes of aiming at aerial, naval, and coastal targets on the basis of the derived values. The aiming [sighting] procedure can proceed automatically, semi-automatically, or manually, and the weapons are fitted out with appropriate receiver units from which the settings can be read off (Fig. 23). All of these receiver units are synchronized with the computer center.

With automatic aiming the weapons can be set into firing position by means of remote control without interference on the part of the gun layers. In the case of semi-automatic aiming the sighting angles worked out at the computer center are synchronously transmitted to the receiver instruments mounted at the weapons. The coarse and fine reading scales of the receiver instruments are needed because it is impossible to mark all calibrations on an exact scale. Each scale division in the case of the coarse reading scale corresponds to a magnitude of 100 TD (a thousandth of the distance), and each scale division of the fine reading scale amounts to 1 or 2 TD. Frequently, the expression TD is
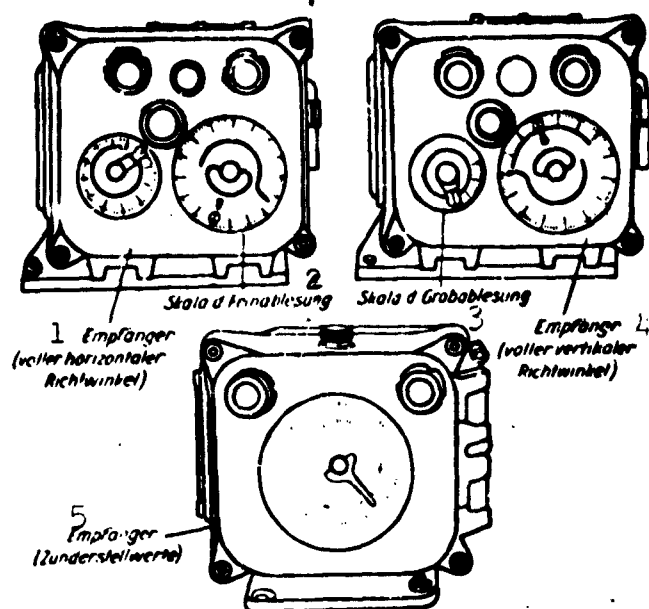
Fig. 23. Receiver units. 1) Receiver
(total horizontal sighting angle);
2) fine reading scale; 3) coarse
reading scale; 4) receiver (total
vertical sighting angle); 5) receiver
(fuse settings).

also rendered as scale divisions. A scale division is equivalent to
3.6 minutes of arc. With a complete rotation of the fine reading scale
the coarse reading scale shifts through a single scale division. In
the case of fine reading one generally speaks of small scale divisions
whereas in the case of coarse reading the reference is to large scale
divisions.

Pointers are seated on the rotor axes of the receivers and corres-
ponding indication markers have temporarily been applied to the sta-
tors. During the course of the aiming process the pointers are rotated
through the magnitude of the received firing settings. The receiver in-
struments are tuned so that its indicators [pointers] and indication
markers are set at zero when the barrel of the weapon at zero degrees
elevation coincides in direction with the plane of the ship diameter.
The stator of the receiver is mechanically connected to the correspond-
ing elevating and traversing mechanisms. By turning the elevation and
traversing mechanism drives, the gun layers align the calibrations
with the indicators on the rotors and thus impart the desired position
to the weapon. If the actual indicator calibration is aligned at the
corresponding pointer, a red signal lamp flashes.

In a number of fire-control systems the calibration markings of the receiver are permanent. In this case the rotors of the receivers are mechanically connected to the elevation and traversing mechanisms. Upon receipt of the total sighting angles, the indicators are deflected through corresponding magnitudes from the permanent calibration markings.

Here again the gun layers align the indicators and calibration markings, thus setting the barrel of the weapon into the required position. The gun layers must continuously align the coarse-reading indicators first with the permanent calibration marking, and then carry out the alignment of the fine-scale indicator.

The continuous transmission of sighting data and the alignment of the needle position relative to the calibrations keeps the weapons continuously directed in accordance with the sighting angle worked out at the computer station. In addition, the weapons are equipped with special receivers which are marked with scales indicting the fuse settings. The construction of such a receiver is similar to that of the sighting data receivers.

Peripheral Instruments

The weapons are fitted out with instruments for transmission of commands and with switches by means of which the various firing circuits can be effected, corresponding to the position. In addition, the weapons have firing blocks and limiters which prevent firing in undesired directions. Frequently, weapons are fitted out with simplified fire-control mechanisms. Every weapon is provided with sights which may be employed independently against visible aerial, naval, and coastal targets in the event of a breakdown in the fire-control equipment.

Remote Controls

Follow-up systems were dealt with briefly in the previous section. These are also known as remote-control systems. These systems are employed to aim weapons automatically, rapidly, and accurately on the basis of the initial data. This sighting procedure is possible because in the case of remote control involving power drives the electrical pulses transmitted by the fire-control equipment are converted into mechanical work which is utilized to drive the sighting mechanisms.

Since the electrical pulses which are carried from the coordinate transformer to the receivers are too weak in order to perform useful work, they are applied to amplifiers. The pulses are amplified in the
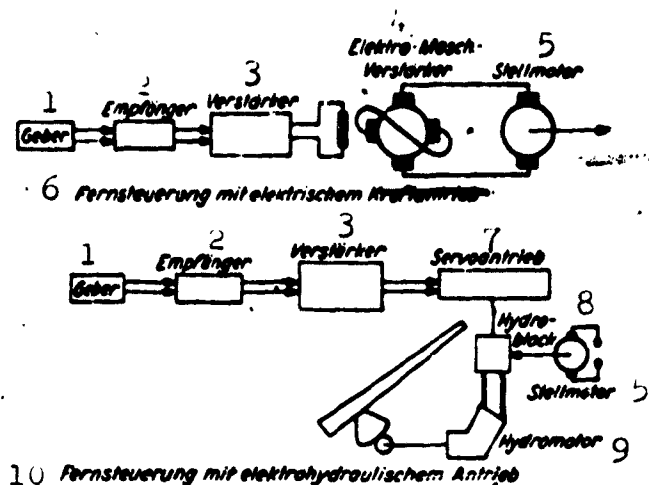
Fig. 24. Remote controls. 1) Transmitter; 2) receiver; 3) amplifier; 4) dynamo-electric amplifier; 5) servomotor; 6) remote control with electrical power drive; 7) servodrive; 8) hydraulic unit; 9) hydraulic motor; 10) remote control with electrohydraulic drive.

amplifiers. Then these pulses are transmitted to the control units which complete the aiming operation by means of the power drives (Fig. 24). The power drives can be subdivided into electrical and electrohydraulic drives.

In the case of electrical power drives the signal voltage from the amplifier is also applied to a dynamo-electric amplifier where it is again amplified and applied to the servomotor that is connected to the corresponding sighting mechanism. At the present time it is the electrohydraulic drives that are primarily in use, with the electric motor of the latter connected to a hydraulic velocity regulator (the hydraulic drive) which can be used to achieve constant changes in the sighting speed. In this case the signal from the amplifier is carried over a corresponding control unit and converted there into mechanical work. This work is used by the hydraulic drive which consists of the hydraulic unit and the hydraulic motor (Fig. 25). The shaft of the hydraulic motor is connected with the sighting mechanism provided for this purpose. The hydraulic unit and the hydraulic motor are connected to one another through the pressurized oil lines. The shaft of the hydraulic unit transmits the rotational motion to the cylinder block through a linkage. The cylinder block is provided with boreholes through which

the pistons move. The piston rods are connected to the driveshaft. The bottom cylinder castings have oval orifices through which the oil is either drawn in or pressed out, corresponding to the motion of the pistons. The cylinder block can change position. This change in position is achieved through a control unit provided for this purpose. When the driving motor drives the shaft of the hydraulic unit at constant velocity and the driveshaft forms a certain angle with the piston rods, the pistons execute both rotational and translational motion. During the course of a single shaft revolution each pistion reciprocates once between the hindmost and foremost positions. The pistons which move to the rear during the rotational motion draw in oil during this phase and those which move forward press the oil into the pressure lines.
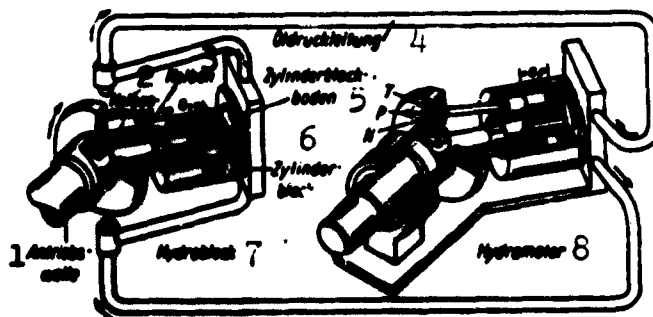
Fig. 25. Construction and operation of a hydraulic drive. 1) Driveshaft; 2) piston rod; 3) piston; 4) oil pressure line; 5) bottom cylinder castings; 6) cylinder block; 7) hydraulic unit; 8) hydraulic motor.

The piston stroke is a function of the angle of the hydraulic unit. The larger the angle, the greater the piston stroke (a) and correspondingly the drawn in quantity of oil. If the angle has a value of zero, oil is neither drawn in nor forced into the lines, regardless of the rotational motion of the driveshaft. The oil passes into the pressure lines from the cylinders of the hydraulic unit through the distributor housing and then moves from the lines into the cylinders of the hydrau-

lic motor where it exerts the corresponding pressure against the pis-
tons of the hydraulic motor.

In terms of design the hydraulic motor is similar to the hydraulic
unit. The difference lies in the fact that the hydraulic motor forms a
permanent angle with the end of the shaft, whereas the hydraulic motor
develops maximum efficiency. The pressure P is transmitted from the
pistons through the piston rods to the end of the shaft. The force P is
composed of the components N and T because of the angle.

The actual component N is applied to the point of piston-rod en-
gagement and forms the tangent at the arc of the circle that is des-
cribed by the rotational motion of the ends of the piston rods in the
distributor housing.

The components N thus produce the rotational motion of the shaft
end. The angular velocity of the shaft end is a function of the quanti-
ty of oil that is forced into the cylinder block of the hydraulic motor
per unit time. The direction of shaft-end rotation is a function of the
angle of the hydraulic unit. This angle may be negative or positive;
this determines the corresponding direction of rotation.

The electrohydraulic drives exhibit high efficiency and ensure
great sighting speeds of sufficient accuracy.

FIRING PREPARATION

Modern aerial targets are extremely fast and as a result spend out
a short period of time in the firing zone. This circumstance alters the
initial data for firing very rapidly and makes it necessary to attack
aerial targets with effective fire, without zeroing in. Extensive and
thorough preparations are therefore necessary for operations against
aerial targets. These preparations include:

the preparation of all materials;

the preparation of the fire-control equipment;

and the preparation of the ammunition.

The success of the firing operation depends in great measure on the quality of the preparatory work.
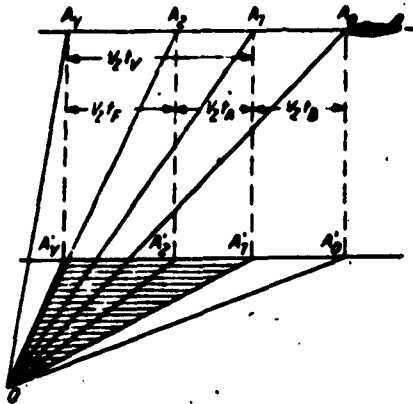
Fig. 26. Solution of the firing problem.

The firing preparation in the case of anti-aircraft artillery of medium caliber can be divided into preliminary preparation (prior to detection of target) and final preparation (after receipt of target indication).

Preliminary preparation involves all corrections that affect the firing procedure, although these are independent of the target. It is during this period of preparation that the weapons are checked out, the fire-control equipment connected, and the ammunition cleared. The preliminary preparation is subdivided into ballistic and meteorological preparation. Normal ballistic conditions require that the barrels be new, that the propellant charge coincide with tabular values, that the temperatures of the propellant charges amount to +15° C, and that the weight and shape of the shells coincide with the specifications. Normal meteorological conditions, on the other hand, stipulate that the wind speeds for all altitudes be of zero value, that the air density coincide with the tabular values, and that the air pressure, temperature, and humidity coincide with the previously determined values.

The meteorological preparation is undertaken in accordance with a "Balta" report (Balta = ballistic daily correction) that is transmitted periodically for purposes of computation. If the degree of barrel wear, propellant-charge temperature, shell weight, and changes in meteorological factors are known, it becomes possible to determine appropriate

corrections from corresponding tables in order to derive the percentag· changes in the muzzle velocity ΔVo_{sum} for the given instant of time an· to derive the total deviation in air density (ΔLDo_{sum}) from normal con· ditions.

All of these corrections are fed into the computer. In the case of firing without a computer, these correction factors can be taken into consideration only partially. The final preparation begins with receip· of target indication and concludes with the computation of the spatial lead point A_y at which the shell and the target will meet (Fig. 26).

The computation of this lead point is known as the solution of the firing problem. The fire-control equipment has the function of ascertaining the coordinates of the lead point at which the target and the missile are to meet. In order to determine the lead point A_y it is necessary to determine the motion of the target exactly, and also to ascertain the muzzle velocity during the preliminary preparation for firing.

The motion of the target is established by the artillery radar stations, with continuous monitoring of the instantaneous target coordinates (range, bearing, and target elevation). The time required for the determination of the instantaneous target coordinates is known as the observation time t_B. For the actual solution of the firing problem, for the transmission of the computed data to the weapons, and for the loading and sighting procedures a time t_A is required, this time known as the operating time. In addition, the flying time t_F of the missile to the lead point must be taken into consideration. The operating time t_A and the flight time t_F together total the so-called lead time t_V (Fig. 26).

It is advantageous to keep this time as low as possible, in order to diminish the effect of changes in target motion, since otherwise the

firing problem cannot be solved exactly.

The nature of target motion during the period of the lead time must be established on the basis of a thorough study of the tactical-engineering characteristics and deployment practices of enemy aerial targets. In this case we speak of target-motion hypotheses.

There are a number of such target-motion hypotheses. Frequent use was made of the hypothesis according to which the target, during the lead time, moves along a straight line and without evasive action in any plane. Such a hypothesis provides adequate characterization of target motion and permits the solution of the firing problem against both horizontal-flying targets and dive bombers.

In addition to the target coordinates, the parameters of motion must be known in order to solve the firing problem, i.e., it is necessary to know the magnitudes which determine the nature of the target's motion together with the instantaneous coordinates. The target-motion parameters are determined in the computer, and this determination is based on the rate of change for the instantaneous coordinates.

In the case of ships not fitted out with fire-control equipment, the motion parameters of the target are estimated. The firing problem is resolved on the basis of the measured instantaneous coordinates and the derived motion parameters of the target, the lead triangles A_yOA_1 and $A'_yOA'_1$ being constructed in this case, the lead point A_y (Fig. 26) then being calculated. In modern fire-control installations the firing problem is solved for the horizontal plane, while the light anti-aircraft artillery solves the firing problem in the slant plane by means of automatic and front ring sights. The coordinates of the lead point calculated in the computer are transmitted to the coordinate transformer where the rolling motion of the ship is taken into consideration. The total firing angles are transmitted from the coordinate transformer

by means of follow-up systems to the elevation and traversing mechanisms of the weapons and the barrels are aligned so that the projectiles meet the target. The detonation of the projectiles at the point A_y is ensured either by means of a time fuse which is set in accordance with the firing range determined by the computer, or it is ensured by means of a radar fuse which is actuated in the vicinity of the target. In the event of a failure on the part of the computer or if no such equipment is available, the weapons are sighted on the basis of the elevation and lead-point values. The sights are set for these magnitudes or the magnitudes can be determined by means of special sights if the weapons are appropriately equipped. The final preparation is thus a combination of several operations, whose function it is to determine the initial values for the first salvo. Individually, these operations involve:

the determination of the instantaneous target coordinates;

the derivation of the target motion parameters;

the solution of the firing problem;

the determination of the final sighting data for the weapons;

and the determination of the fuse-setting values.

The final initial values are then fed to the weapons; the latter can then be aimed and loaded.

In dynamic terms the entire procedure then unfolds as follows: after the target has been detected by the ship, the combat alarm is given and the crew assures its combat and command stations. All weapons and technical facilities are readied for combat and information pertaining to target indication is provided by the main command post. Target indication serves simultantaneously as the command to open fire. Upon receipt of the target indication the individual in charge of the firing procedure issues the corresponding orders. The fire-control equipment begins the computation of the initial data. Simultaneously, the flow of

ammunition is started. The salvos are fired at the prescribed rate of fire. No firing corrections are undertaken. The individual in charge of the firing operation only observes the effectiveness of the fire against the target.
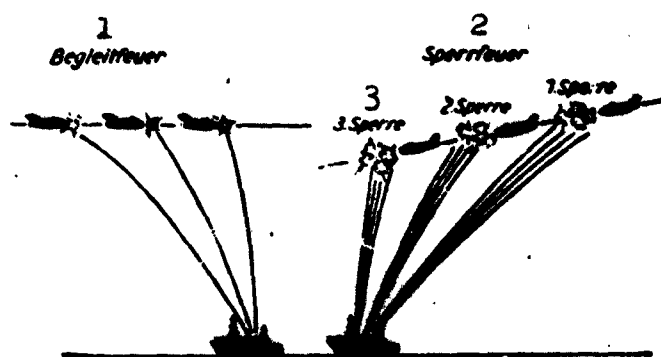
Fig. 27. Anti-aircraft artillery firing operations. 1) Accompanying fire; 2) barrage fire; 3) barrage.

Indications of firing effectiveness are either target damage or violent target maneuvers, if the detonation points are in the vicinity of the target. The firing operation is halted as soon as the target is damaged or after the target has left the firing zone. The firing is stopped at the command "Battery, cease firing."

Depending on the situation, the firing may be carried out in accordance with various methods; accompanying fire is the basic method, the detonation points continuously following the target in this case. The firing is executed in salvos in accordance with a predetermined rate of fire. Firing in salvos demands disciplined performance on the part of the gun crews and facilitates observation. The initial data for each salvo are worked out either by means of the fire-control equipment or taken from tables, if the firing procedure is being carried out by means of such tables. This method is extremely exact and may be employed for operations against any aerial targets.

Another method involves the firing of barrages (Fig. 27). This method is employed when a surprise aerial attack is under way and no

time is available for the preparation of the fire-control equipment. Each barrage consists of a number of salvos with an exact fuse setting. We speak of a mobile barrage when we move from one barrage to another, with a determined number of salvos fire per barrage. The last barrage is designated as a nonmobile barrage, since the fuse setting of this barrage is employed until the target is either damaged or leaves the firing area. Nonmobile and mobile barrages combine to form the so-called barrage firing whose density can be increased by the firing operations of the large-caliber weapons of heavy battleships. The barrages are fired at a maximum rate of fire.

Automatic weapons are used for operations against rockets, pursuit bomber aircraft, dive bombers, and torpedo aircraft which operate at altitudes below 3500 meters and represent direct danger to the ship. Surprise and the short duration of the aerial attacks impose great requirements upon the weapon crews. The crews must be thoroughly familiar with the deployment characteristics of the enemy air force, they must be able to work rapidly, and they must be in a position to conduct true and accurate firing operations.

Preparation for firing for automatic weapons also consists of preliminary and final preparation.

Generally, in the case of the utilization of automatic weapons that are not fitted out with fire-control equipment the speed of the target and the angle of dive are estimated, the range being based on information from a range finder, or also estimated.

The preparatory operations prior to firing should, if at all possible, be concluded upon entry of the target within the range of the weapon. Continuous fire is the basic method employed with automatic weapons when firing against aerial targets. Depending on the range, long or short bursts are fired and the intermediate periods of time are used

for fire corrections. Upon receipt of target indication the individual in charge of the firing operation issues the corresponding commands. The gun layers set the speed, range, and angle of dive on the automatic sight, the gun loader feeds the ammunition, and firing can then be commenced.

Aboard a ship fire control may be carried out from a central point or it may be decentralized. In the case of centralized fire control, the individual in charge of the firing operation oversees all weapons simultaneously, whereas in the case of decentralized fire control the weapons are used by batteries or in groups.

If possible, the fire of several ships should be concentrated against a single aerial target. In this case we speak of concentrated fire, which produces the most rapid successful results.

Anti-Aircraft Rockets

Modern aircraft and rockets exhibit outstanding tactical flight characteristics which are expressed particularly in high speeds and altitudes. As a result operations against such targets with conventional artillery is extraordinarily difficult and impossible at high altitudes.

The positive defense of ships at sea against aerial attacks demands that action be taken against the enemy air force at a point in time at which the enemy aircraft are still at considerable distances from the target.

The anti-aircraft rockets, representing a new stage in the development of anti-aircraft facilities, are weapons capable of satisfactorily meeting this requirement.

The design of special anti-aircraft rockets had been started in many countries as early as the 2nd World War. Initially, these involved reaction-thrust projectiles without automatic control systems, these projectiles capable of carrying large charge loads very rapidly to

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their targets. Detonation was accomplished by means of radar fuses in
the proximity of the target. These initial designs were superceded by
anti-aircraft rockets equipped with automatic control and guidance sys-
tems.

Fig. 28. Dual launching site for the
Terrier rockets aboard the US Navy
cruiser Canberra.

The range and altitude of anti-aircraft rockets considerably ex-
ceed those of conventional anti-aircraft artillery. The electronic
equipment used in the target-seeking heads and the great flight speeds
of the anti-aircraft rockets make it possible not only to operate
against enemy aircraft but also to maintain a defense capability
against guided rocket missiles.

From the tactical standpoint, anti-aircraft rockets are classified
as ground-air or ship-air categories. Anti-aircraft rockets are used
aboard a wide range of ship classes.

Anti-aircraft rockets exhibit excellent aerodynamic properties
which permit of high flight velocities. The electronic equipment of the
target-seeking heads and the noncontact fuses automatically detonate
the explosive charge in the proximity of the target.

Anti-aircraft rockets are launched from special launching sites
which are mounted aboard ship deck. The launching sites are fitted out

with guide rails by means of which the rockets during the launching procedure assume the required initial direction. In addition, the launching sites are provided with the technical facilities for loadin~, aiming, and stabilization. It is the function of the stabilization fac- ilities to eliminate the pitch and roll motions of the ship in order to facilitate the launching and guidance procedures. The elevation and traversing mechanisms are similar in design to the elevation and tra- versing equipment of [conventional] anti-aircraft weapons. The launching sites are aimed automatically on the basis of information received from the fire-control installations.

Unlike the situation with artillery weapons, in the case of the launching sites there are no recoil forces and for this reason the foundations must not be constructed as stably as otherwise. The launch- ing sites may be provided with a single guide rail, although there are versions with two and four rails. The gun mount for the launching of rockets is executed in the shape of a cylinder, the pivot bearing mounted in the upper half of the cylinder. This half can rotate through $360°$. The gun mount is connected rigidly to the foundation. The trunni- ons seated in the pivot bearing carry the guide rails (Fig. 28). The elevation and traversing mechanism for the rotation of the upper half of the gun mount and for the aiming of the guide rails are housed in the gun mount, as are all of the cables. The maximum elevation of the guide rails amounts to $90°$. The rocket magazine is situated beneath the launching installations; the rockets are raised by means of elevators.

During the loading procedure the guide rails are raised into ver- tical position and are then positioned perpendicular to the elevator shafts. The lower portion of the guide rails is wedge shaped and as they snap into position the covering hatch of the elevator shaft is au- tomatically opened. The advancing rockets slide into the guide rails to

the top stopping block and in this manner assume the firing position (Fig. 29). Either one or two rockets can be launched simultaneously.
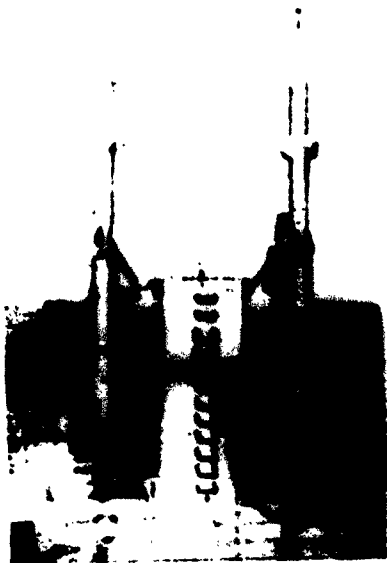
Tests have demonstrated that the anti-aircraft rockets have assumed the leading position in the aerial defense of ships. The downing of the U-2 reconnaissance aircraft over the Soviet Union on 1 May 1960 demonstrated the superiority of Soviet anti-aircraft rockets. In addition to the positive characteristics, rockets naturally also exhibit a number of shortcomings. Rocket guidance systems may be subject to interference on the part of special stations. The rate of fire is none too great and restricts their utilization, particularly in the case of the sudden appearance of low-flying aircraft and rockets. In this

Fig. 29. Dual launching site in loading position. The Terrier rockets are taken from both sides of the shafts and inserted into the guide rails.

case the conventional anti-aircraft artillery comes into action and serves to overcome this drawback. At the present time there exist a variety of guidance systems for rockets. These include programmed, remote-controlled, target-seeking, and combined guidance systems.

In the case of programmed guidance, the rocket is guided to the target in accordance with a predetermined program. All instruments provided for guidance purposes are housed directly aboard the rocket.

In the case of remote-control guidance, however, commands are issued to the on-board instruments from a control center situated outside of the rocket.

In the case of target-seeking guidance, the target-seeking heads ensure the exploitation of heat, radar, optical, or similar target con-

trasts. In order to achieve a significant increase in hit probability on the part of the rocket, target-seeking guidance [homing] is generally employed in the last phase of the flight.

Combined guidance consists of a combination of the above-mentioned systems (e.g., programmed and homing guidance, or remote-control and homing guidance). In the case of anti-aircraft rockets it is the remote control and homing guidance systems that are generally encountered.

In the case of a remote-control system, the simplest system is command guidance. The operator keeps the motions of the rocket and the target under observation, transmits certain commands to the rocket by means of radio and these are received by the receiving unit of the rocket. The control surfaces are actuated correspondingly by means of power drives and the rocket is guided to the target (Fig. 30).
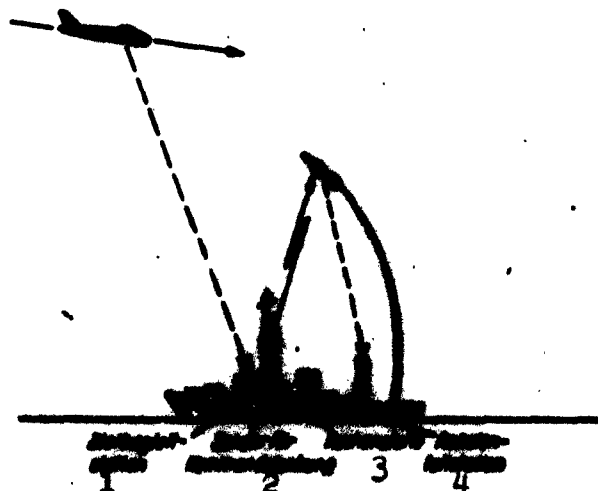
Fig. 30. Command guidance system.
1) Target track radar; 2) command
link; 3) computer; 4) missile
track radar.

When using command guidance, missile track and target track radar units are put into operation and on the basis of the information supplied from these the velocity, altitude, and heading of the target can be determined, and the required guidance signals can be worked out. However, only a single rocket can continuously be guided toward a tar-

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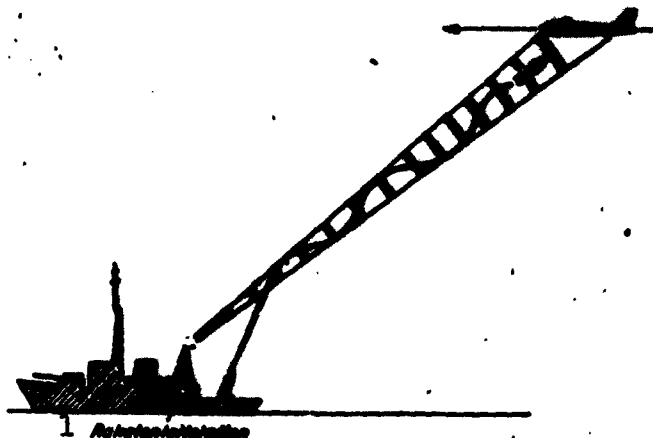
Fig. 31. Beam-rider guidance. 1) Missile
track radar.

get with this system, thus significantly reducing the probability of
hitting the target.

Another guidance procedure for anti-aircraft rockets involves the
continuous and automatic maintenance of the rocket in the radar beam of
a radar station. The target is continuously tracked with this narrow
radar beam. The radar station thus serves the double function of track-
ing both the target and the rocket as well as guiding the rocket (Fig.
31). The on-board instruments prevent the rocket from leaving the radar
beam and thus guide the rocket to the target. The advantage of this
procedure lies in the fact that the radar beam may be employed simul-
taneously for the guidance of several rockets to the target, thus s ig-
nificantly raising the probability of hitting the target.

Target-seeking [homing] ensures high probability of hit, even
against small targets executing evasive maneuvers.

The homing procedures can be subdivided into three forms, i.e.,
passive, active, and semiactive.

Passive homing [target seeking] involves a procedure in which the
homing head of the rocket is set to react to a certain target contrast.
This may be based on heat, electromagnetic waves, light, or some simi-

lar contrast. The angle between the direction of rocket motion and the bearing to the target is determined in the homing head, and by means of corresponding control-surface variations the rocket independently is guided toward the target contrast.

The active guidance system is based on the exploitation of the radar principle. A miniature transmitter is built into the rocket and this emits electromagnetic waves in a clearly defined sector. Should targets appear in this sector, the reflected signal is picked up by a receiver in the rocket and this receiver correspondingly serves to actuate the control surfaces and thus guides the rocket to the target (Fig. 32).
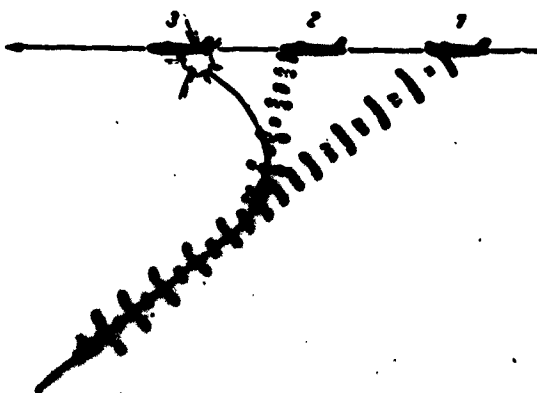
Fig. 32. Active homing guidance.

Semiactive homing guidance also relies on the utilization of the radar principle, although in this case the rocket is fitted out only with a receiving unit. The emission of electromagnetic waves is the function of the radar unit provided for this purpose aboard the ship. The reflected signal is picked up by the receiving unit in the homing head. The rocket receiver serves to actuate tne control surfaces and guides the rocket to the target. Anti-aircraft rockets carry large demolition charges which are capable of completely destroying any aerial targets. According to information from the press, in the United States the anti-aircraft rockets of the Terrier and Talos type have proved

themselves + > be the most suitable. Aircraft carriers, cruisers, des-
troyers, a.d special air-defense ships are equipped with these rockets,
for purposes of convoy duty.

The slant range of the Terrier I rocket is 25 to 30 km, the maxi-
mum altitude is at around 14 km, and the reports indicate a velocity of
700 m/sec. The Talos anti-aircraft rocket exhibits a slant range in ex-
cess of 100 km, a maximum altitude of 21 to 23 km, and a flight veloci-
ty of up to 1200 m/sec. This rocket can be fitted out with a nuclear
weapon and is not intended for operations against aerial targets, but
rather for combat operations against ground and large surface targets.

Modernized versions of the aforementioned rockets, such as the
Terrier II, the Talos-W, and the Talos-L have already come into being,
and these exhibit greater range and velocities. The guidance of the
Terrier rocket is of the beam-rider variety and involves homing guid-
ance at the terminal phase of the flight. The rate of fire amounts to
2 rockets per guide rail per minute. The rockets are launched by means
of a solid rocket which is jettisoned after 3 seconds. The continued
flight is powered by the sustainer engine. The detonation of the war-
head is carried out by means of a noncontact fuse.

If the developmental work toward increasing range and maximum al-
titudes for anti-aircraft rockets is proceeding on the one hand, par-
ticular attention is being devoted to the development of anti-aircraft
rockets for operations against low-flying targets.

Ships are being fitted out with the Sea-Cat anti-aircraft rockets
in Great Britain, these rockets being small and suitable for operations
against low-flying aerial targets (Fig. 33).

These rockets consist of a booster and a sustainer engine. The
rockets are 1473 mm long and the wingspan is given as 635 mm.

Command guidance is used for the Sea-Cat. The operator, by means

Fig. 33. Seaslug type anti-aircraft
rocket (similar to the Sea-Cat) after
launching.

of an optical system, determines the position of the target upon re-
ceipt of the target indicatior. After the target becomes visible, the
operator launches the rocket and by means of commands guides the rocket
toward the target; in this case, the rocket must be kept continuously
along the line of sight. To facilitate observation, the rocket is pro-
vided with a tracer composition. If the target cannot be visually de-
tected, only a radar unit can be employed for purposes of acquisition.
The operator then follows the radar pulses of the target and rocket,
aligns these, and guides the rocket to the target.

Each firing installation has 4 rockets which, however, can only be
launched successively and guided toward the target. The limited practi-
cal sightirg range restricts the utilization of the Sea-Cat anti-air-
craft rockets, since no more than two launchings can be carried out
against faet-flying aerial targete.

The general trend in the development of anti-aircraft rockets is
toward enlargement of range, flight velocity, probability of hit, and
effectiveness at the target.

Effectiveness at the target is to be raised through utilization of
nuclear weapons. Accordingly, American specialists are of the opinion

that nuclear weapons with a TNT equivalent of 800 to 5000 Mp [sic] are suitable for rockets of the ground-air class, since with such a weapon an entire bomber group, even in widespread formation, could be destroyed.

COMBAT EXPERIENCE IN UTILIZATION OF AERIAL COMBAT FACILITIES

During the 2nd World War the air forces were used on a large scale at all fronts and by all navies to accomplish a great variety of operations. The air force proved to be the dominant force, and carried out unanticipated strikes against targets lying deep behind the enemy lines

The air force destroyed military ports and important rear targets. The air force played a great part in the number of ships sunk on the high seas and in harbors.

As a rule the capitalist countries, as soon as they had adequately strong air forces at their disposal, began to conduct the war with aerial attacks. It should be stressed in this case that combat ships have always been the main targets for aerial attack. The attacking side always seeks to inflict losses against the enemy naval forces in order to gain naval superiority, thus to achieve from advantageous conditions for operations on the land. The 2nd World War and the Great Fatherland War abound with examples demonstrating the importance of the organization of air defense for ships and bases.

The successful aerial attacks of the British Royal Air Force against the Italian military port at Taranto in November of 1940, at which time 3 Italian battleships and 2 cruisers were destroyed, the Japanese air attack against Pearl Harbor in December of 1941, and the sinking of the English battleship Prince of Wales and of the battle cruiser Repulse can be attributed to the exploitation of the element of surprise and to the excessively long time required for the attainment of combat readiness on the part of the air-defense facilities of these

ships and bases.

An extremely instructive example for poor air-defense organization at a base and the ships harbored within is offered by the actions of the American Navy at the time of the Japanese air attack against the naval base at Pearl Harbor.

On the eve of Japan's entry into the war, the American high command, in recognition of the important role of the Hawaiian Islands, recalled the Pacific Fleet. Pearl Harbor was chosen as the home base of the fleet. This decision resulted in a high concentration of combat ships and auxiliary vessels in Pearl Harbor. As a result, 6 battleships, 9 cruisers, 20 destroyers, 5 submarines, and auxiliary vessels were concentrated at the base at the same time.

The moorings of the ships were totally inadequately from the standpoint of air-defense requirements. The ships were not decentralized. Seven battleships were moored at the docks in double rows and thus offered convenient targets for an air attack. The moorings were maintained for long periods of time and were not changed. Thus the Japanese high command had exact information at its disposal with respect to the number of ships and their positions.

There were sufficient air-defense facilities on the island of Oahu, where Pearl Harbor is situated, but because of a lack of uniformity in the orders that were issued it was impossible to organize the effective coordination of these facilities. Although information regarding the readying of a Japanese air attack against Pearl Harbor was at hand, aerial reconnaissance was conducted on a limited scale and the combat readiness of the air-defense facilities of the naval base and of the ships stationed there was organized completely inadequately.

The events which took place on 7 December 1941 at Pearl Harbor are described as follows in the book entitled "The American Aircraft Car-

riers During the Pacific War" by Sherman:

The 7th of December, 1941, was a Sunday. The officers and men wer
contemplating how best to take advantage of this resort area. The regu
lar watch was on duty at the base and aboard the ships; a number of an
ti-aircraft weapons were staffed with skeleton crews. A great portion
of the ammunition was stored in the magazines and was not available fc
immediate utilization. The morning role call was about to start aboard
the ships and for reasons of convenience the sailors had opened a num-
ber of watertight bulkheads and hatches. As usual, the call for the
morning formation was given at 07:55 AM. It was at this time that un-
identified aircraft appeared over Ford Island which lies in the center
of the Pearl Harbor naval base. Within a short time additional aircraf
appeared unexpectedly from all directions. Without delay the aircraft
began to release bombs and torpedoes against the heavy ships at anchor
at the docks or buoys. The individuals witnessing these events were un-
able to believe their eyes. Ten aircraft dived against naval-aircraft
targets on Ford Island. While these employed normal combat tactics in
attacking the aircraft standing on the runways, other aircraft were at-
tacking the ships.

The Japanese high command trailed the target in order to inflict
the greatest possible losses on the American Pacific Fleet and in order
to prevent their own losses so as to have superiority over the scene of
naval operations. In order to prevent their premature detection, the
Japanese decided to employ a grouping of 6 small fast aircraft carriers
with extremely well trained crews in order to ensure the success of the
extensive air attack. The Japanese were thus successful in taking full
advantage of the element of surprise.

The first strike of the Japanese air force was directed against
the airfields and anti-aircraft batteries of this naval base, and sub-

Fig. 34. Pearl Harbor after the Japanese air attack on 7 December 1941. In the foreground, the burned out hulks of the destroyers Cassin and Downes, in the background, the damaged battleship Pennsylvania.

sequently the Japanese high command concentrated the strikes against the ships lying in Pearl Harbor. The attacks were carried out primarily by aircraft groups, with approximately 2 to 3 aircraft designated for each ship. The torpedo aircraft approached at low altitudes below 500 m, with div⌐ bombers and bomber aircraft attacking simultaneously. With the first attack, a number of battleships suffered one or more torpedo hits. The dive bombers showered the heavy ships with bombs. Between the first and second attacks, flights of aircraft went into action from four directions.

To ensure success, the second and third strikes were carried out with a great number of aircraft, the third strike ending at 10:00 hours.

In order to conceal the position of the aircraft carriers, upon

completion of their assignment the aircraft flew off in various directions.

As a result of this air attack the American navy suffered significant losses   (Fig. 34). Four (4) battleships were sunk, as were 2 destroyers, a mine layer and an old battleship that was being used as a target vessel. Serious damage was inflicted on 4 battleships, many cruisers, and destroyers. The Navy and Marine Corp suffered losses of 2835 men, including 20bu dead. The Army lost 600 men. Moreover, 92 aircraft of the Marine Air Corps were destroyed and 31 damaged; the Army suffered losses of 96 aircraft.

The great losses can be attributed to weak organization of air defense and to the poor level of training for the artillery personnel, since defense operations against small aircraft groupings by means of anti-aircraft fire on the part of battleships and cruisers should not have permitted the inflicting of such high losses. The Japanese losses were insignificant. They amounted to 29 aircraft, one submarine, and 5 m'iget submarines.

An example of poor air-defense organization on the open sea is the sinking of the English battleship Prince of Wales and of the battle-cruiser Repulse by the Japanes Air Force on 10 December 1941, as these ships were to undertake operations in conjunction with ground forces along the Malayan coast. These were the first battleships that were sunk during the course of the 2nd World War. The air force was operating independently in this case and the ships were under way in full combat readiness.

The Prince of Wales was a modern battleship displacing 35,000 tons. The ship was heavily armored, carried ten 356-mm weapons, and a large number of anti-aircraft weapons. The cruiser Repulse was armed with 380-mm weapons and with heavy anti-aircraft artillery. In total, the

cruiser had 90 anti-aircraft barrels at its disposal.

On the morning of 10 December 1941 one of the four flanking destroyers spotted a squadron of 9 aircraft at an altitude of 3000 meters, moving in from the south-east on the port side. Without deviating from their course, these aircraft attacked the ships at 11:20 hours. Despite the timely detection of the targets, the anti-aircraft weapons delayed opening fire, and this naval squadron had absolutely no fighter escort.

With the first approach the cruiser Repulse suffered a bomb hit and burst into flames. After the bombers had attacked, the torpedo aircraft followed. One torpedo struck the stern and inflicted serious damage to the rudder installation. Within a short period of time another group of torpedo aircraft appeared and this group attacked the battleship Prince of Wales and inflicted a number of additional hits on this ship. As a result of shipped water the ship started to list heavily. A third torpedo finally ripped the stern away and eliminated completely the ability of the vessel to execute evasive maneuvers.

Despite the heavy anti-aircraft fire the torpedo aircraft continued their attack and climbed rapidly after releasing their torpedoes in order to get out of the artillery range. The last torpedo strike which crippled the Prince of Wales virtually converted it into a target ship; after a number of additional bomb hits, the battleship keeled over. At the same time the cruiser Repulse was struck by torpedoes on both sides and sank soon thereafter.

The Japanese employed simple attack procedures in this operation, but nevertheless the anti-aircraft fire was opened late. A number of aircraft were able to drop their bombs or release their torpedoes before the start of the anti-aircraft firing. This resulted in favorable conditions for the following aircraft groups.

The cited examples show that at the beginning of the 2nd World War

the Americans and British underestimated the utilization of air power at sea.

The Great Fatherland War is rich in examples of air defense.

The high level of training and the watchfulness of the anti-aircraft troops made it possible successfully to frustrate the initial air attacks of the fascist air force against Murmansk, Kronstadt, Odessa, and Sevastopol by means of the air defense facilities of the Navy.

At the beginning of the war the fascist navy was extremely active in the Baltic and Black Seas, and in addition the fascist submarines and surface vessels were operating in the BarentsSea. These circumstances hindered the deployment of Soviet combat ships and made life at the bases difficult. Ships and bases were continuously subjected to enemy air attacks.

The fascists set themselves the goal, during the very first days of the war, to destroy the naval power through extensive air attacks. They inflicted heavy strikes against bases, bombarded harbor installations, piers, arsenals, fuel depots, and other rear installations important for the fleet, and also attacked convoys on the open sea.

Air defense required precise organization. It functioned in exemplary fashion during the transfer of ships from Tallinn to Kronstadt in August 1941.

During the Great Fatherland War a large part of the Baltic Fleet was at anchor in Tallinn and supported ground operations by artillery fire, thus delaying the entry of the fascists into the capital of Estonia. Because of superiority in terms of strength and facilities, the fascists were able during the first half of August to reach the coast at Narva and thus to surround Tallinn by land. The ships as a result were separated from their own ground forces. The north and south coasts of the Gulf of Finland were in enemy hands. The fleet no longer was in

possession of the airfields at which the naval air forces were previously stationed. In view of this situation approximately 200 ships and transports were given orders to break through the Kronstadt. This was an extremely daring operation.

Taking advantage of their air superiority, the fascists attacked the ships continuously, from the very first days of the transfer operation, and showered the ships with bombs. The entire burden of the battle was on the shoulders of the ship artillery forces who had to repel more than 10 air attacks daily. It was primarily the combat ships that were subjected to air attacks, e.g., the flagship, the Kirov. On 25 August 1941 this ship was attacked eleven times, once simultaneously by approximately 50 aircraft. On this day 136 bombs were dropped on this ship. By outstanding maneuvering and with effective artillery fire the cruiser was able to withdraw despite the attacks of the fascist air force.

The convoy, which consisted of transports and auxiliary craft, had a particularly difficult day on 29 August. While the combat ships had extensive anti-aircraft weaponry at their disposal, well organized air defense, and exhibited relatively high speeds, so that they were able to accomplish the trip successfully, the slow moving transports and auxiliary ships on the other hand, were only poorly armed, and for these the trip was particularly difficult and dangerous. The fascist air force trailed these slow soviet ships throughout the entire 29th of August.

As a result, for example, the training ship Leningrad Soviet was subjected to 100 air attacks, but it was not struck by a single bomb.

The transport vessel, the Kazakhstan, repelled the air attacks of the enemy throughout the entire day and although it had lost power the daring and energetic actions of the crew made it possible to extin-

guish the fires that had been set and to repair all damage.

On the Gotland-Kronstadt leg, the ships and the transport vessels picked up the fighter escort of the Navy Air Force. As a result, the fascists ceased any further action against the convoy. On 30 August the ships and transports reached Kronstadt.

The enemy sought to penetrate the city and his operations on the ground were closely coordinated with his strikes against the ships of the Baltic Red Banner Fleet. In the short period of time from 21 through 23 September 1941 the enemy sent 400 aircraft against the city of Kronstadt and against the ships at anchor in the roads.

The battleship, the October Revolution, during the months of September through October 1941 withstood more than 30 massive attacks.

The first fascist air attack against Sevastopol failed. As the fascist aircraft approached the vicinity of Sevastopol, they were surprised by heavy anti-aircraft fire from the combined facilities of the anti-aircraft artillery of the navy base. The fascist aircraft could not make out the ships and targets of the base because of the excellent camouflage. The aircraft dropped their bombs without aiming and a number of the aircraft failed to reach their targets at all.

However, the situation in the Black Sea soon underwent a temporary change. The fascists succeeded in taking a portion of the coast and the Crimean Peninsula. Odessa, Sevastopol, and a number of other cities along the Black Sea were besieged by land. The supply of weapons and equipment, as well as other military goods, thus was only possible by sea. The Naval High Command implemented all measures in order to supply the besieged cities with personnal and material from the Caucasian coast and to evacuate the wounded as well as the civilian population.

The fascists employed approximately 1000 aircraft of various types from the Crimean Peninsula against the ships of the Black Sea Fleet,

including special aircraft for operations against naval targets. Under these circumstances, the artillery personnal aboard the ships bore an extremely great responsibility. At the end of December of 1941 the Black Sea Fleet carried out landings in the port cities of Kerch and Feodossiya. The cruiser Red Crimea and Red Caucasus participated in the landing Feodossiya. Early on the morning of 29 December 1941 the cruiser Red Caucasus tied up at the outside jetty of Feodossiya under enemy artillery fire and disembarked the landing forces. The cruiser Red Crimea on the other hand disembarked its landing troops by means of landing ships and barges.

After the landing forces had been disembarked, the cruisers moved on to provide artillery support.

With the coming of dawn, the enemy air force went into action, and attacked the ships continuously, with brief intervals. The air attacks continued throughout the entire day, lasting until the onset of darkness. During this period the cruiser Red Caucasus was attacked fourteen times, while the cruiser Red Crimea was subjected to eleven attacks. Through outstanding maneuvering action and intensive artillery fire the ships were able to evade the bombs. Because of their courage and resistance, and in view of their high level of training, the crews carried out the assignments of landing disembarkation and support without permitting any serious damage to their ships.

The voyage of the flagship Tashkent on 26 June 1942 from Novorossik to Sevastopol during the last days of the defense of this city represents an excellent example which demonstrates the difficult conditions under which combat operations were carried out against the enemy air force at sea. Despite the continuous air attacks during the voyage, through maneuvering and intensive anti-aircraft fire the ship was able to repulse the air attacks and to supply the city with 1000 troops and

important war materiel. After having taken on 2000 wounded, the ship left Sevastopol on the night of the second day. In a period of four hours 86 aircraft attacked the ship. Outstanding valor and mastery of technique made it possible for the crew to carry out its assignment. The anti-aircraft gunners forced the enemy through their intense fire to break formation, disrupted a directed bomb release, and downed a number of enemy aircraft. The assignment was carried out with honor.

In order to reduce the effectiveness of the enemy air attacks, the ships and transport vessels of the Black Sea Fleet laid down smoke screens.

The air power of the Black Sea Fleet attacked the fascist air- fields and other important targets, thus reducing the capability of the enemy to carry out bombing attacks against ships at sea.

The heroic behavior of the battleship Sevastopol, of the cruisers Red Caucasus and Red Crimea, the flagships Tashkent and Kharkov, as well as of a number of other ships of the Black Sea Fleet represents a glorious page in the history of the soviet fleet.

During the time that the soviet artillery was engaged in bitter combat with the enemy air forces in the Baltic and Black Seas, their brothers in combat in the Far North were successfully repelling the fascist air attacks against the naval forces in the Barent Sea and thus secured the sealanes for the Allied convoys.

The convoys represented an excellent target for enemy attacks on the high seas and particularly during unloading operations. The Arctic Fleet did a terrific job in defending its own transports and ships as well as those of the Allies against air attack. Outstanding knowledge was demonstrated by the artillery personnel of the cruisers Gremyashi, Sokrushitel'nyy, Kuybyshev, and Urutski during convoy duty in the Yel- low Sea.

On the morning of 18 September 1942 the destroyer Gremyashi spotted a group of torpedo aircraft on the horizon, approaching in low-level flight. These aircraft attacked the convoy from the rear. At the same time, the convoy was attacked by bombers. The ships opened fire with all weapons, including the heavy caliber weapons. A total of 35 attacks were repelled, and the destroyers shot down 5 aircraft and damaged 4. At the same time, 15 English ships, also present in the convoy, destroyed 10 enemy aircraft.

THE ORGANIZATION OF AIR DEFENSE ABOARD COMBAT VESSELS UNDER CONDITIONS OF MODERN WARFARE

The extensive development in the facilities of aerial attack leads to a continuous rise in the potentials of employing these facilities against naval targets. The air force today is in a position to execute the greatest variety of assignments and can, at the same time, achieve significantly greater results than were possible during the 2nd World War.

The constant danger from the air requires the utilization of substantial means of air defense aboard ships in order constantly to ensure the readiness of ships for air defense. More modern air-defense facilities are constantly being developed and new protective measures provided for the secure defense of ships against aerial attack. Air defense today is regarded as one of the most important means of defense. Proceeding from the combat potentials of the means of aerial attack, it is the opinion in the capitalist lands that air defense of ships at sea under modern conditions must carry out the following tasks:

the execution of preparatory strikes against the air facilities of the enemy and his carriers;

prompt detection of aerial targets;

combat with aerial targets by means of anti-aircraft rockets and

conventional anti-aircraft artillery;

employment of actice interference;

and the decentralization of naval units, as well as constant change of position.

Pursuit aircraft are drawn into the air-defense system, and these can be deployed from aircraft carriers or fixed positions; in addition use can be made of anti-aircraft rockets, the anti-aircraft artillery of ships and bases, and finally of radar facilities.

The radar facilities have the function of detecting the aerial targets of the enemy promptly, to recognize same, and to keep them under observation. In addition, the radar facilities are extremely important for the guidance of interceptors to the enemy targets.

The pursuit aircraft included in the air-defense system of ships at sea are to be regarded as the primary striking force. These aircraft must constantly be ready for utilization and must be capable of operations at all altitudes. The interception and destruction of enemy aircraft and rockets is carried out by so-called interceptors that can be guided to the enemy from ships or from special aircraft. The interceptors exhibit extraordinarily great velocities. These aircraft are fitted out with automatic radar equipment. The interception procedure becomes automatic as soon as the interceptor has been guided sufficiently close to the target.

If the situation calls for such an operation, a so-called aerial alert can be organized over ships at sea at various altitudes. This operation is employed when there is a possibility of an unexpected aerial attack. The aerial alert operations are so set up that the aircraft can, in short order, be formed to meet the enemy at the point from which he is likely to strike.

The deployment of pursuit aircraft is greatly dependent on weather

conditions, and the maneuverability of the pursuit is limited because of the great flight velocities and these aircraft cannot therefore be employed at all times to protect the ships against aerial attack. For this reason it becomes necessary to include other facilities in the defense system, and we have reference here to such weapons anti-aircraft rockets and conventional anti-aircraft weapons. At low altitudes the utilization of conventional anti-aircraft weapons, primarily of automatic weapons, is more advantageous than the utilization of pursuit aircraft. On this basis the air defense must always be organized so that the air-defense facilities can always be employed with the greatest effect.

Fig. 35. Effective air-defense zones. 1) Effective zone (W.Z.) of pursuit aircraft; 2) effective zone of anti-aircraft rockets; 3) effective zone of anti-aircraft artillery.

The automatic weapons are to be used primarily for operations against low-flying and low-attacking targets that endanger the ship in its immediate vicinity. Of course, anti-aircraft weapons can also be used for targets at altitudes between 12,000 and 14,000 meters, although the combat potentials in this case are exceedingly limited. The anti-aircraft rockets are superior in range to the conventional anti-aircraft artillery. For this reason the former are also used against distant aerial targets, and namely in an effective zone having a radius in excess of 50 km.

As a rule, outside of this zone it is the pursuit aircraft that come into operation. On the basis of the combat potentials of the individual air-defense facilities, we therefore distinguish the following

ones of the air-defense system:

the effective zone of the anti-aircraft artillery;

the effective zone of the anti-aircraft rockets;

and the effective zone of the pursuit forces (Fig. 35).

This subdivision is necessary so as to prevent the mutual inter-
erence of friendly forces and facilities in the defense system.

It follows clearly from the aforesaid that the air defense under
onditions primarily requires good organization of cooperation among
1 air-defense forces.

The deployment of defense facilities available to ships must be
ordinates precisely with the operations of the pursuit forces. The
ti-aircraft artillery of ships in coastal or base areas must operate
coordination with the ground-based air-defense forces.

The prompt detection of aerial targets and recognition of the lat-
r becomes particularly important, because the prompt establishment of
mbat readiness on the part of all forces and air-defense facilities
pends on this. Moreover, the defense units should be informed of the
ture and features of the approaching targets, since the proper selec-
on of targets also plays an important role in the successful repul-
on of the attack.

One of the most important observation facilities used aboard ships
the afore-mentioned radar unit. These units, however, exhibit only
latively limited range and leave but little time for the readying of
 defense facilities of the ships. The lower the altitude at which
 air targets are approaching their goal, the greater the limitations
osed on radar range. In order, nevertheless, to detect enemy air
gets promptly, to recognize these, and to forwarn the ships, special
ps and aircraft are set up for purposes of distant early warning, i.
. the so-called radar outposts.

Radar-equipped aircraft are in a position to keep a large area under observation and contribute to a significant expansion of the time between the detection of the target and the actual attack. The radar outposts must be set up so far in advance of the site being protected that on the one hand the ships can be warned in sufficient time to prepare their defense operations and on the other hand to provide sufficient time for the launching of the interceptors and to be available for the guidance of these aircraft to the target.
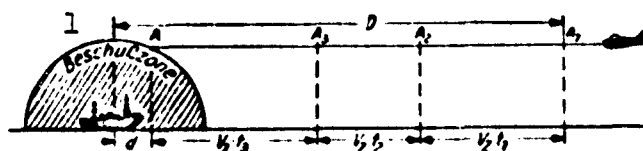

Fig. 36. Aerial-target detection range. 1) Firing zone.

The required detection range is calculated on the basis of the following formula:

$$D = V_Z \cdot t + d \ [m];$$

V_Z is the velocity of the target [m/sec]; t is the time required in order to prepare the defense facilities of the ships (in seconds) [sec]; d is the horizontal range for the given caliber as a function of target altitude [m].

The time t is composed of the following periods of time (Fig. 36):

t_1 is the time required for the preparation of air-defense facilities;

t_2 is the time required for the readying of the first salvo;

t_3 is the flight time required in order to cover the over-all range.

On the basis of information contained in the foreign press, approximately one minute is required for the launching of an anti-aircraft rocket and for the preparation of the necessary materials. Ap-

proximately 30 seconds are needed for the preparation prior to firing, and 30 seconds is the flight time.

Since the situation in the air undergoes extremely rapid change, the guidance of the forces and air-defenses facilities (on board as well) must be automated. Until very recently a large number of observer and signal personnel were required for the transmission of information and commands. The present level of development for electronic units makes it possible to automate many parts of the process, thus achieving considerable savings in time and labor. The over-all process of target observation and recognition, the evaluation of the aerial situation, and the transmission of corresponding initial data and information to the air-defense facilities can today be completely automated.

Alert stages are set up in order to maintain continuous combat readiness. Depending on the alert ordered, the action stations are manned either completely or in part. During the course of normal daily duties, of course only a portion of the available personnel and facilities are available for immediate commencement of fire. For this reason, the rapid manning of all action stations in response to the appropriate signal is of great importance in order to make the ship completely ready for air defense in the shortest possible period of time.

The expansion of the range for air-defense facilities led to a change in the altitudes at which air weapons can be employed. Until very recently the maximum altitude ceilings for the utilization of air combat facilities were regarded as effective, whereas at the present time the minimum altitude ceilings are regarded as the most effective altitudes of operation for air-combat facilities, since in this manner the detection of targets is hindered and thus the interception and destruction of such targets is made more difficult.

By means of preparatory strikes against enemy rocket launching
sites, airfields, and carrier facilities it should become possible very
rapidly to attain air superiority and thus to ensure favorable condi-
tions for air defense. It is the primary responsibility of the air
force in this case to sink ships mounting rockets and aircraft carriers,
whereas the responsibility of the pursuit-aircraft forces is defined
particularly as the destruction of such enemy aircraft as are equipped
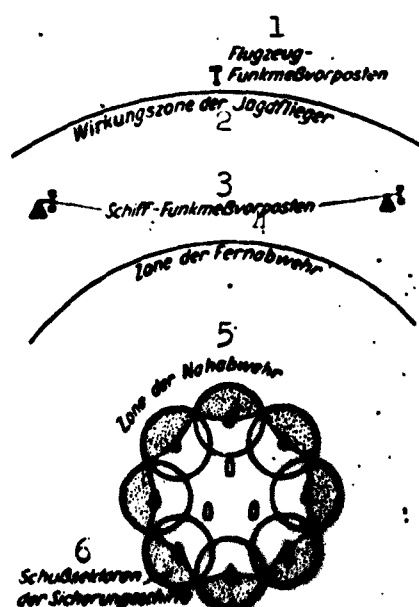with rockets.

Fig. 37. Possible versions
of combat deployment under
air-defense conditions. 1)
Aircraft-radar outposts; 2)
pursuit-aircraft effective
zone; 3) ship-radar outpost;
4) distant defense zone; 5)
proximity defense zone; 6)
firing sectors of security
ships.

The military specialists in the
West are of the opinion that rocket-
equipped surface vessels and submarines
can contribute significantly to the at-
tainment of air superiority by directing
their strikes against rocket-carrying
vessels and aircraft carriers.

In addition to the extensive util-
ization of active air-defense facilities,
the success of the enemy air force can
be significantly diminished by maintain-
ing the secrecy of transport operations,
by taking camouflage into consideration,
and by choosing an appropriate formation
for the voyage. As a rule, ships assume
a formation which precludes success on
the part of an enemy air attack. This formation is based on the attempt
to make certain that a single stick of bombs cannot strike more than 2
ships simultaneously, while still maintaining the capacity to provide
mutual protection through multiple anti-aircraft fire, and without neg-
lecting the conditions of 360° observation.

The combat deployment should be such that the security ships cir-
cling around the object to be protected form zones of near and distant
defense (Figs. 36 and 37).

The purpose of the near-defense zone is to defend against enemy
aerial targets that seek to attack the ships at great distances. For
this purpose interceptors and anti-aircraft rockets are used. It is the
function to the near-defense zone fo destroy penetrating enemy rockets
and aircraft. Anti-aircraft rockets and conventional anti-aircraft wea-
pons are used for this purpose as well.

Depending on the organization of the combat deployment, a distant
observation zone is set up, as well as a 360° observation zone for each
individual ship. The security ships, in addition to the 360° observa-
tion, also set up a reinforced observation procedure in the established
firing sector for each given ship. The firing sectors of the adjacent
security ships overlap and thus provide defense against enemy aerial
targets which are approaching from all directions through multiple an-
ti-aircraft fire. The ships for which security is being provided also
set up a 360° observation procedure.

Should it be likely that the enemy is using nuclear weapons, the
ships are moved apart in the formation in order to preclude the simul-
taneous sinking of 2 ships with a single nuclear charge. Nevertheless,
in this situation the possibility of massed fire should still be main-
tained.

Since the enemy air force is in a position very rapidly and with
fewer losses than its fleet to attack bases and ports, it becomes nec-
essary to implement a number of measures in order to provide secure
defense of the ships in the bases. The moorings in the bases must be
covered so as to ensure the most advantageous deployment of the air-de-
fense facilities of the ships and to preclude the simultaneous damaging

of several ships with a single rocket or stick of bombs.

The coordinated action of air-defense facilities aboard ships and at the bases must also be set up in a precisely organized fashion. As enemy rockets or aircraft approach a base, interceptors are first sent into action to destroy these with conventional on-board weapons or rockets of the air-to-air class. If the enemy air targets have penetrated through the interceptor zone, anti-aircraft rockets are used against the enemy. The anti-aircraft rockets exhibit a relatively high probability of hit; the on-board explosive is adequate for total destruction of an aircraft. The primary drawback of the anti-aircraft rockets involves the impossibility of simultaneously guiding a large number of anti-aircraft rockets from a single guidance station. It is therefore possible, in the case of a massed attack in which the number of enemy aircraft exceeds the simultaneously launched number of anti-aircraft rockets, that a number of aircraft will reach the desired target.

It is also not out of the question that the aerial targets will be intercepted too late or not at all and that the fire directed at these aerial targets with the anti-aircraft rockets failed in its purpose. In this case the full defense burden falls on the anti-aircraft artillery. The previously considered air-defense organization for ships at sea and in bases does not, in the opinion of western specialists, completely ensure the secure defense of the potential targets, particularly if the aerial targets are moving at supersonic velocities. For these reasons it is recommended to provide for interference with the enemy guidance systems and to secure antimissile missiles.

Interference with guidance systems is achieved by means of radio jammers aboard the ships and aircraft or housed in defensive rockets. Of course, passive interference means may also be employed, i.e., metal

foil ejected from aircraft, paint coatings that reduce the reflection properties, and angled reflectors exhibiting high reflecting power.

Ejected metal foil forms a natural impediment to the propagating electromagnetic waves and can, in this manner, affect a portion of the guidance system.

The angle reflectors which are set up in the vicinity of the site; being protected form decoy targets which serve the function of misdirecting the rockets from their actual targets.

In addition, artificially produced pressure waves can cause damage to individual instruments of the guidance systems and thus lead to a deflection of the rockets from their preset flight trajectories.

The problem of combating ballistic rockets is particularly difficult. In the opinion of American specialists, this problem is composed of the following: the acquisition, interception, and the destruction of the ballistic rocket.

While operations against targets flying at subsonic velocities were possible despite great difficulties, defense against ballistic rockets poses many more difficult problems. In the opinion of western naval experts and on the basis of information in the press, the problem of operating against supersonic rockets has not been completely solved, since the acquisition of such targets is particularly difficult. This difficulty is explained by the circumstance that the relative approach velocity between target and anti-aircraft rocket is extremely great and as a result the over-all process of guiding the anti-aircraft rocket toward the target must be automated.

Another problem that must be resolved involves the timely detonation of the demolition charge of the anti-aircraft rocket. The existing radar fuses do not always provide detonation at the desired time. For this reason it may occur that the attacking target can penetrate the
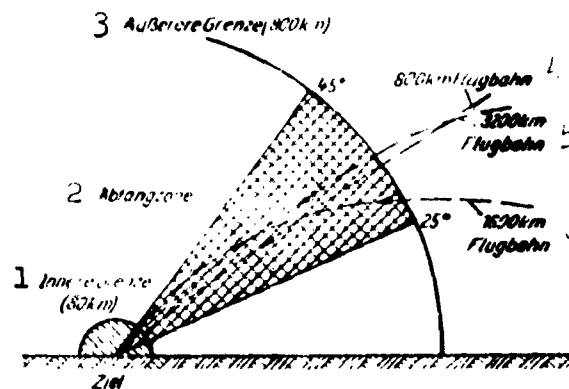
Fig. 38. Possible zone of ballis-
tic-rocket interception. 1) Inside
boundary (80 km); 2) interception
zone; 3) outside boundary (800 km);
4) 800 km trajectory; 5) 3200 km
trajectory; 6) 1600 km trajectory.

detonation zone of the anti-aircraft rocket in advance of the detona-
tion of the latter.

Despite the great difficulties associated with the execution of
guidance systems and fuses for anti-airdraft rockets, much work is
being done abroad on the design of defensive measures against rockets.
The "antimissile missiles" have been built as the primary means of de-
fense against ballistic rockets, these missiles exhibiting extraordin-
arily good tactical flight characteristics. However, readily deployable
rockets of this type are available only to the Soviet Union, which has
solved the problem of rocket defense.

The utilization of antimissile missiles requires, first of all, a
reliable distant detection system. In the opinion of western experts
the detection stations and antimissile-missiles must exhibit flight en-
gineering characteristics permitting the detection and destruction of
intercontinental rockets approaching at ranges in excess of 1500 km, at
flight velocities of up to 7 km/sec and at altitudes as high as 1000 km.

The direction-finder stations in the distant detection system must
be connected to electronic computers in order to calculate the trajec-

tories of the ballistic rockets and to determine their points of impac in sufficient time. The values determined in this manner are then transmitted to the antimissile-missile guidance stations.

The last 700-800 km of the flight trajectory of a ballistic rocke must be monitored with extreme care, since random or predetermined deviations may occur during this phase. The above-mentioned segment of the trajectory is regarded by western experts as the extreme limit of the acquisition zone for ballistic rockets. The inside boundary of the acquisition zone is defined by the minimum distance and altitude at which the detonation of a nuclear charge cannot damage the site being protected. One generally assumes figures of around 80 km, with the effective range of a nuclear warhead generally assumed as 30 km. Proceeding from this, the antimissile-missiles must exhibit a range of 120 to 160 km (Fig. 38).

The analysis of the combat characteristics of ballistic rockets which have been made operational or are soon to become operational in various countries leads to the conclusion that the launching of an antimissile-missile and the guidance of this missile to the target cannot be permitted to involve a period of time longer than a single minute, since otherwise destruction becomes impossible.

The antimissile-missiles are designed as multistage rockets. Each antimissile-missile may weigh as much as 5 Mp [sic] and is fitted out with special control and guidance units.

According to information contained in the western press the engine must develop the required thrust within a period of 60 seconds during the powered phase of the antimissile-trajectory (137 km), with the last stage weighing only 45 kp [sic]. The contruction of the antimissile-missile must be capable of withstanding a G force of 100 with a turning radius of 38 km and an angular velocity of 9.2^{o}/sec.

Nuclear charges with a TNT equivalent of 20 kilotons have been proposed for the destruction of intercontinental rockets. This charge should be sufficient to damage a ballistic rocket at a distance of 300 meters. On the other hand, antimissile-missiles with nuclear charges of 20 Megatons ensure the destruction of ballistic rockets, the permissible error in this case as high as 3 km. Because of the limited dimensions and weight of the last stage, the utilization of nuclear warheads is highly unlikely.

The antimissiles developed in America include the Nike-Zeus and Wizard types. The Nike-Zeus antimissile-missile is currently the most perfect development of the Nike-Hercules antimissile-aircraft rocket. We can see from the available foreign press that the Nike-Zeus antimissile-missile is a three stage rocket. The second stage is powered by a liquid-fueled engine, whereas the launch is achieved the means of a solid engine. The liquid engine is gimbal mounted and control is achieved through jet vanes. The third stage, which includes the warhead and the homing device, is also powered by a solid engine, as is the first stage. The range of this antimissile-missile amounts to approximately 320 km.

The antimissile-missiles can be provided with both conventional and nuclear warheads for the destruction of ballistic rockets. The velocity of the antimissile-missiles is given as 1100 m/sec. Command guidance is preferred as the guidance system. Proposals have been made to use infrared homing devices, since ballistic rockets fly virtually beyond the atmosphere and thus offer an excellent heat contrast.

In the case of the Wizard antimissile-missile we are dealing with a single-stage solid-propellant rocket exhibiting a flight range of approximately 1600 km. Boosters have been developed for these rockets to make possible the interception of ballistic rockets at altitudes of up

to 800 km. A nuclear charge can be housed in the warhead of the Wiza antimissile-missile. This rocket is used with an extremely complicat remote-control system. An infrared homing head is provided for the t minal phase of the flight of this rocket.

In the United States work is proceeding on several versions for the deployment of Nike-Zeus type rockets. The system intended for ro et defense makes up the main version. This system encompasses three dar-unit types (early-warning systems, recognition units, and target track radar units) as well as a certain number of batteries for the launching of the antimissile-missiles.

The distant early-warning radar units are switched on after receipt of certain signals and emit continuously in the direction of d ger over a range of 1600 km. After acquisition of the target has ber completed, 2 stations pick up the target. These stations track the t get and carry out recognition, determine the target coordinates, and compute the nature of the trajectory. The range of these stations ma) reach to 1000 km. Each identification unit is connected to 4 batterie of Nike-Zeus antimissile-missiles. Two (2) tracking radars are includ in each antimissile-missile battery, and the range of these units con to approximately 320 km. One of these units track the approaching tar get, whereas the other unit tracks the Nike-Zeus antimissile-missile launched for defense toward the target. The computed data of the two units are then fed to electronic computers which issue the required guidance commands to the rockets. It is clear that little time can be spent on control operations prior to the launch, and for this reason the antimissile-missiles must at all times be ready for action. They are always stored in vertical position at the batteries and must constantly be ready for launching.

The number of batteries that are employed for the defense of a

given object is a function of the nature of said object. In the opini

of western experts, the batteries must be constructed so that regard-

less of what is happening on the outside they can be utilized, even i

the surrounding area has been totally destroyed. This requirement can

be satisfied only if the batteries are built deep underground.

The Wizard system exhibits a number of advantages with respect t

the Nike-Zeus system, because it can be employed against ballistic

rockets executing evasive maneuvers. In recent times it has become i.

practice to speak of yet another system that is intended for utiliza-

tion against antimissile-missiles and this system is known as the Plat

system. This system relies heavily on the Nike-Zeus system, although

is considerably more maneuverable and better deployable from the oper

tional standpoint, particularly for the defense of individual objects

under field conditions. In addition, the Plato system works out the i

itial data more rapidly than does the Nike-Zeus system.

The individual units for the Plato system, the electronic equip-

ment, the antennas, and the launching ramps are mounted on motorized

vehicles. The guidance is achieved by means of corresponding commands.

It is to be assumed that in the future a similar system for anti-

missile-missiles will also be developed for ships.

American specialists are of the opinion that the hit probability

for the Nike-Zeus and Wizard antimissile-missiles amounts to approxi-

mately 25 percent. From the standpoint of certainty, it is calculated

that from 10 to 20 antimissile-missiles are required for the destruc-

tion of a single ballistic rocket. Work is also being done in the Unit

ed States on a new defense against intercontinental ballistic rockets.

Attempts are being made to emit bundles of fast neutrons, e.g., at the

detonation of a nuclear weapon in outer space. It is the opinion of

American specialists that it is possible for these bundles of neutrons

to produce a chain reaction in the nuclear charges of rockets and thus to achieve a premature detonation, before the rocket can endanger the target.

An altitude of 150 km has been proposed as the minimum altitude at which warheads with nuclear charges can be detonated. The idea of using a bundle of neutrons thus involves the **filling of a part of outer space with infinitely small "detonators."**

CONCLUSION

The descriptions presented here make cl a: :u the reader the prob-
lems involved in the air defense aboard ships. It must be underscored
that only precise organization and faultless cooperation among all per-
sonnel can ensure the successful utilization of air-defense facilities.
The failure to meet these requirements on the part of only a single
crew member can result in serious losses. Considering the fact that
aircraft today develop velocities in excess of 600 m/sec, the reponsit-
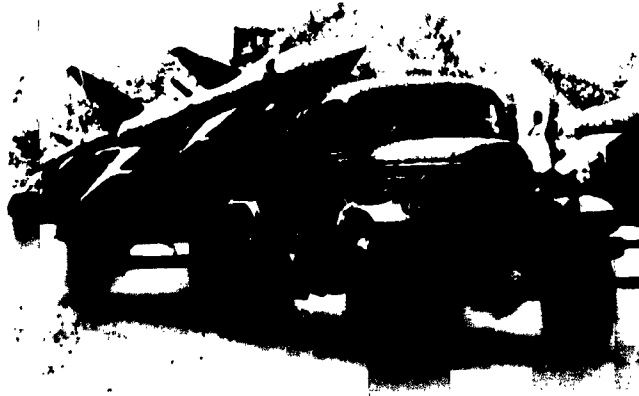

Fig. 39. Air defense of the National Peoples Army of the German Demc-
cratic Republic. The American spy, Powers, was shot down with a rocket
of this type. Similar rockets are also being used aboard soviet ships.

ility of the radar crews becomes evident from this fact alone. Success
in combat is literally a matter of seconds. Delay in commencement of
fire can, under certain circumstances, result in the loss of the entire
ship. It is important therefore that techniques are thoroughly mastered,
because only in this manner is high action readiness ensured. The crews
must be capable of employing their techniques under difficult condi-

tions. To accomplish this it is necessary that training be organized and carried out under realistic conditions during peacetime. Excellent results in combat training are, after all, the foundation for success in any future battle.

The extensive and multipurpose equipment available to a ship demands high technical skills on the part of all members of the crew, since the higher these qualifications, the fewer the number of technical breakdowns and disruptions. Of course, technical know-how alone is not enough in order to be able to use the weapons successfully. The tactical principles of deployment on the part of the enemy must also be well known in order to achieve victory in battle. The storage and main-tenance of combat equipment is of great significance. Weapons and instruments that have been properly cared for are less subject to disruptions and contribute to the maintenance of the continuous combat read-ness. The requirements imposed on pursuit pilots and anti-aircraft artillery men in the air-defense system are high. The pilots must be capable of operating at great altitudes and to deal securely with difficult meteorological conditions. It is not an easy task to detect the targets promptly and to destroy them. Flight over water involves a number of features for the pursuit pilots with which they must be thorroughly familiar. The anti-aircraft artillerymen must be thoroughly trained in their coordination with the pursuit-aircraft forces. Their primary assignment involves the successful combating of a given target with the first salvo. Day and night, they must not neglect their guard watches. In conclusion, it should be pointed out once again that the requirement of continuous maintenance of combat and deployment readiness can only be achieved when all members of the crews show high political-moral characteristics, are true to the Fatherland, trust in their equipment, constantly seek to achieve outstanding training results, and

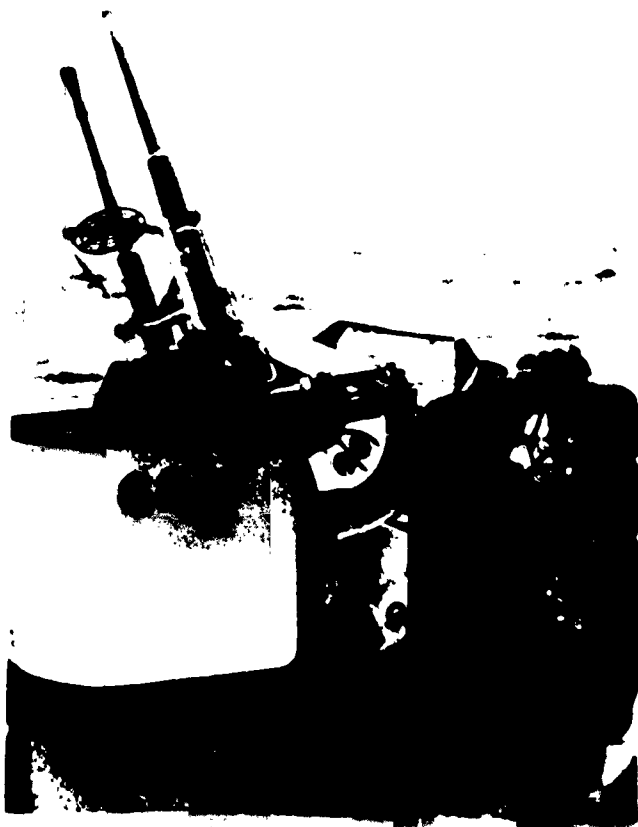always execute assignments rapidly and with discipline.

Fig. 40. Modern double gun mount aboard
a ship of the Peoples Navy.

Fig. 41. Rocket launching ramp aboard
a soviet rocket cruiser.

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